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THE DYAKS OF BORNEO.

THE Dyaks of Borneo are regarded by Mr. A. R. Wallace as closely allied to the Malays, and more remotely to the Siamese, Chinese, and other Mongol races. All these are characterized by a reddish-brown or yellowish-brown skin of various shades, by jet-black straight hair, by the scanty or deficient beard, by the rather small or broad nose, and high cheek bones; but none of the Malayan races have the oblique eyes which are characteristic of the typical Mongols. The average stature of the Dyaks is rather above that of the Malays, while it is considerably under that of most Europeans. Their forms are well proportioned, their feet and hands small, and they rarely or never attain the bulk of body so often seen in Malays and Chinese. Mr. Wallace is inclined to rank the Dyaks above the Malays in mental capacity, while in moral character they are greatly superior to them. They are simple and honest, and become the prey of the Malay and Chinese traders, who cheat and plunder them continually. They are more talkative and more lively, less secretive and less suspicious than the Malays, and are therefore pleasanter companions. The Malay boys have little inclination for active sports and games, which form quite a feature in the life of the Dyak youths, who, besides outdoor games of skill and strength, possess a variety of indoor amusements. One wet day, while in a Dyak house, Mr. Wallace thought he would amuse them with something new, so showed them how to make "cat's cradle" with a piece of string. Much to the author's surprise he found that they knew all about it, and even more than he did; and one of the boys took the string and made several new figures which puzzled Mr. Wallace considerably. They then showed him a number of tricks with pieces of string, which seemed quite an amusement with them. Even such apparently trifling matters as these may assist us in forming a true estimate of the Dyak's character and social condition; for we learn thereby that these people have passed beyond the first stage of savage life, in which the struggle for existence absorbs the whole faculties, and in which every thought and idea is connected with war or hunting or the provision of their immediate necessities. The moral character of the Dyaks is undoubtedly high; they are truthful and honest to a remarkable degree. In these and several other matters of morality they rank above most uncivilized and even above many civilized nations. They are temperate in food and drink, and the gross sensuality of the Chinese and Malays is unknown among them. They have the usual fault of all people in a half-civilized state—apathy and dilatoriness—but this is more than outweighed by their many excellent qualities.

The Dyaks, as a race, do not increase very rapidly. The women rarely have more than three or four children. Climate and race have something to do with this, but a more real and efficient cause seems to be the hard labor of the women and the heavy weights they constantly carry. A Dyak woman generally spends the whole day in the field, and carries home every night a heavy load of vegetables and firewood, often for several miles over rough and hilly paths; and not unfrequently has to climb up a rocky mountain by ladders, and over slippery stepping-stones, to an elevation of a thousand feet. Besides this, she has an hour's work every evening pounding rice with a heavy wooden stamper, which violently strains every part of the body. She begins this kind of labor when nine or ten years old, and it never ceases but with the extreme decrepitude of age. So we need not wonder at the limited number of her progeny, but rather be surprised at the successful efforts of nature to prevent the extermination of the race.

The Dyak houses, according to Mr. Wallace, are all raised on posts, and are often two or three hundred feet long and forty or fifty feet wide. The floor is always formed of strips split from large bamboos, so that each may be nearly flat and about three inches wide, and these are firmly tied down with rattan to the joints beneath. The floor, from its elasticity, makes an excellent bed when a mat is spread upon it.

The only dress of the Dyak young men and boys is simple but elegant, and consists of a long "chawat" or waist-cloth which hangs down before and behind. It is generally of blue cotton, ending in three broad bands of red, white, and blue. Those who can afford it wear a handkerchief on the head, which is either red, with a narrow border of gold lace, or of three colors like the chawat. The large, flat, moon-shaped brass earrings, the heavy necklace of white or black beads, rows of brass rings on the arms and legs, and armlets of white shell, all serve to relieve and set off the pure reddish-brown skin and jet black hair. Add to this the little pouch containing materials for betel chewing, and a long, slender knife, both invariably worn at the side, and you have the every-day dress of the young Dyak gentlemen.

For the figure presented herewith to illustrate these remarkable people we are indebted to *La Nature*.

DYAK CHIEF OF BORNEO.—FROM A PHOTOGRAPH.

THE carrier-pigeon service is now in full operation in France, and has been placed under the direction of the Chief of Aerial Communication. The number of birds fed by the Government is 6,000. A number of soldiers and officers have been taught the art of pigeon breeding, and carriers constantly sent from place to place.

POLYDACTYL HORSES, RECENT AND EXTINCT.

By PROFESSOR O. C. MARSH.

IT is said that the aborigines of this country, when they first saw the horses brought over by the Spaniards, named the new animal "the beast with one finger nail." Certainly, the single hoof on each foot is the most marked characteristic of the modern horse, and one on which some of his most valuable qualities depend. The nearest living allies of the horse are the ass and the zebra, and they possess the same pedal peculiarities.

In addition to each main digit of the ordinary horse, however, the anatomist finds concealed beneath the skin two slender metapodial "splint bones," which are evidently the remnants of two other toes, originally possessed by the ancestors of the horse. It is an interesting fact that these splint bones are sometimes quite fully developed, and may even support extra digits, which are much smaller and shorter than the main foot. As these small hoofiets are usually regarded as a serious detriment to the animal, they are generally removed from the colt soon after birth, but in such cases the enlarged splint bones not unfrequently indicate in the adult their former existence.

Numerous cases of extra digits in the horse have been recorded, and in nearly all of them a single lateral hoofiet was present on one of the fore legs. In most instances the occurrence was noted chiefly on account of its rarity, and no record was made of the exact position of the extra hoofs with reference to the main digit, nor of the significance of these useless appendages. Since the attention of the writer was called to the subject, a few years since, he has ascertained that these supernumerary digits are much more common in the horse than has been supposed, and in many cases they appear to indicate a reversion to an early ancestral type.

The figures given on next page represent, (1) the foot of the modern horse in its normal condition, with the splint bones rudimentary; (2) the foot abnormally developed, with one splint bone bearing a small hoofiet; and (3) the foot of an extinct three-toed ancestor of the horse. The feet are all from the left side, and the numbers attached indicate the different digits, counting from the inside. The first and fifth, corresponding to the thumb and little finger of the human hand, are wanting in these figures. A specimen similar to that represented in figure 2, on next page, is preserved in the Museum of Yale College.

The first recorded instances of extra digits in the horse, known to the writer, are two mentioned by George Simon Winter, in his famous book on Horses, published near the beginning of the last century.* One of the horses referred to and figured in this work was "eight-toed," having a small extra digit on the inside of each foot. Winter states that this horse was exhibited in Germany in 1663, and a portrait of it preserved in Cologne. His account was derived from a person who had examined the animal. The other horse described by Winter had a small hoof on the inside of each fore foot, and this steed, Winter states, he had not only seen but ridden.

Geoffroy Saint-Hilaire has recorded the fact that he examined a fœtal horse which was polydactyl on the fore feet, the second foot bearing three nearly equal digits, and the right but two.† Owen has described the right fore foot of a horse with a double hoof, the extra digit being on the inner side, answering to the second digit.‡ Arloing has figured and described similar specimens.§ Leidy has described the right fore leg of a horse with a supernumerary digit on the inner side; and Allen subsequently discussed

* *De Re Equaria*, Nuremberg, 1709.

† *Annales des Sciences Naturelles*, XI., p. 224. Paris, 1827.

‡ Osteological Catalogue, Museum Royal College of Surgeons, Vol. II., p. 587. London, 1853.

§ *Annales des Sciences Naturelles*, VIII., p. 55. 1867.

the same specimen.* A number of other instances have been recorded, showing that extra digits are by no means rare in the modern horse.

The most interesting case of this kind examined personally by the writer is the horse represented in Figure 4. This animal was on exhibition in New Orleans, in the spring of 1878, and Dr. Stanford E. Chaillé of that city first called the attention of the writer to it, and likewise sent a photograph, from which the cut below was made.

This same horse was subsequently brought to the North, and a few days since was on exhibition in New Haven, Conn., where the writer examined him with some care The animal is of small size, about ten years old, and is said to have been foaled in Cuba. He is known among showmen as the "Eight-footed Cuban Horse." With the exception of the extra digits, he is well formed, and doubtless is capable of considerable speed, although some of the exploits claimed for him may fairly be questioned.

The four main hoofs are of the ordinary form and size. The extra digits are all on the inside, and correspond to the index finger of the human hand. They are less than half the size of the principal toes, and none of them reach the ground. An external examination indicates that the metapodial bone of each extra digit is entire, and at its lower end, at least, is not co-ossified with the main cannon bone.

There appear to be two phalanges above the coffin bone in each of these digits, which are thus rendered flexible, especially in a fore and aft direction. There was no indication of "interfering" shown on the inner digits themselves, although it is difficult to see how this could be entirely avoided during rapid motion. The splint bone on the outer side of each leg is apparently of the usual shape and size.

Among the instances of recent polydactyl horses, described to the writer by those who have seen them, are two of special interest. One of these was a colt with three toes on one fore foot, and two on the other. The animal recently

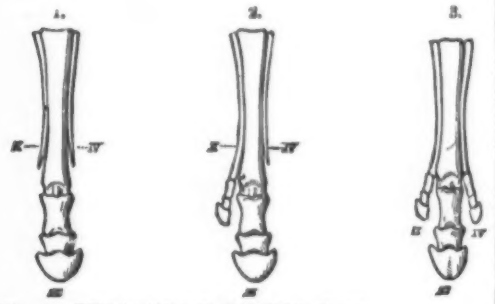


Fig. 1.—FORE FOOT OF HORSE (*Equus*).
Fig. 2.—FORE FOOT OF HORSE WITH EXTRA DIGIT.
Fig. 3.—FORE FOOT OF *HIPPARION*.

died in Ohio. Another is a mare, raised in Indiana, and still living, which is said to have three toes on each fore foot, and a small extra digit on each hind foot. In regard to the latter animal, the writer hopes soon to have more definite information.

Besides the instances mentioned above of extra digits in place in the existing horse, there are many cases on record of true monstrosities, as, for example, additional feet or limbs attached to various portions of the body. Such deformities now admit of classification and explanation, but need not be considered in the present discussion.

In reviewing what is now known of extra digits in the feet of the modern horse, the best authenticated instances appear to fall naturally into two groups. The first of these includes digits which are simply cases of reduplication, quite similar to the extra finger occasionally seen in the human hand. Such deformities are apparently a vegetative repetition, the explanation of which has not yet been satisfactorily determined. The second class includes cases where a true digit is formed, the component bones of which are in their normal position, and in proper relation to the rest of the limb. Such instances appear to be clearly due to reversion to some ancestral type. Some digits, which appear at first sight to belong in the first category, may really illustrate the second, but the converse of this is much less likely to be true. The cases of apparent reversion are of especial interest, and it is important to place on record any information in regard to them, so that they may be compared with extinct allies of the horse.

The cases of extra digits in the horse, so far as at present known, show that these appendages make their appearance more frequently on the fore feet than on the hind feet.

* Proceedings Academy Natural Sciences, Philadelphia, 1871, p. 119, and 1876, p. 99.

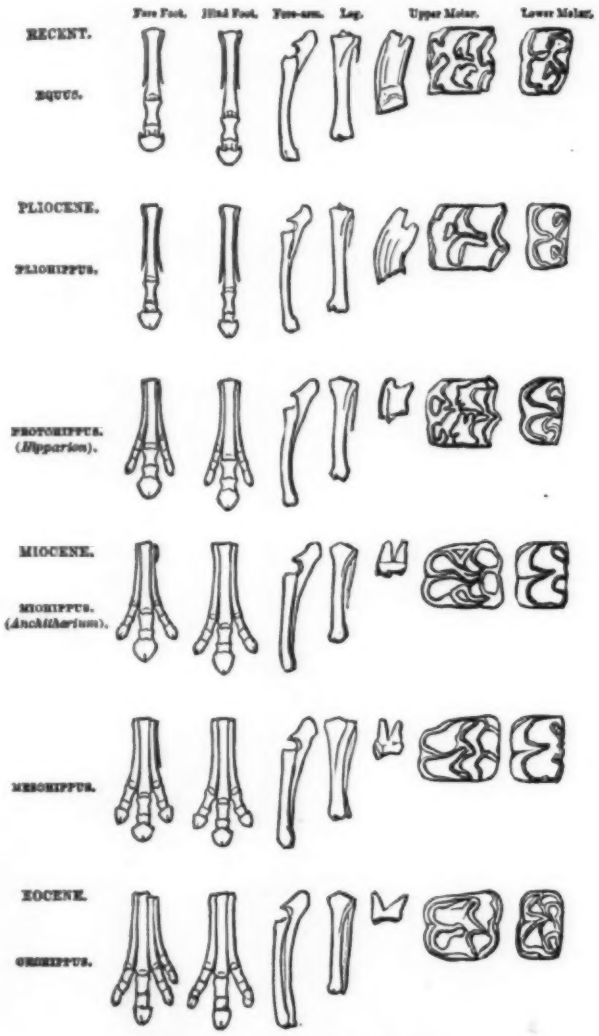
This is precisely what a study of the fossil forms of equine mammals would lead us to anticipate.

Another noticeable peculiarity of these extra digits is their more frequent occurrence on the inside of the main digit, while the outer splint remains rudimentary. This, it must be confessed, is directly opposed to the general law of reduction in the ungulate foot, which, briefly stated, is, that of the five original digits, the first or inner one, first disappears; next, the fifth or outer one; then, the second; and last of all, the fourth. The third always remains as in the horse. It would, therefore, be naturally expected, that when only one additional digit was present, it would be on the outside of the fore foot.

The tendency to interference would seem to be another reason against the retention of the inner digit. Possibly the additional protection which an inside hoodlet would receive might more than counterbalance this influence. Again, the above law is not known to apply to the perissodactyl foot, beyond the first and fifth digits, and if the second digit was originally of greater use than the fourth, and hence was longer retained, an ancestor of the horse may yet be found with the second and third toes alone developed.

In considering these double hoofs of the horse, and with them the well known cleft in the coffin bone of recent and extinct equines, it is important to understand that in no case do they indicate any approach to the true artiodactyl type, as some authors have supposed. The difference between the perissodactyl, or "odd-toed," and artiodactyl, or "even-toed," structure is a profound one, extending to nearly every part of the skeleton, and making two distinct groups of Ungulates. The number of toes has really nothing to do with the true distinction, and hence the terms in use are especially misleading. The real difference, so far as the feet are concerned, is, that in the perissodactyl type the axis of the limb passes through the middle of the third digit (*Mesaxonia*), while in artiodactyls it is outside of this digit (*Paraxonia*), between it and the fourth.

If, now, we turn back to the early ancestors of the horse for an explanation of the supplementary digits which so often make their appearance, we shall not look in vain, especially in this country. America is the original home of



GENEALOGY OF THE HORSE.

the horse, and during the whole of Tertiary time, this continent was occupied with equine mammals, of many and various forms. Although all these became extinct before the discovery of this country, their abundant remains mark out the genealogy of the horse in an almost unbroken succession of forms.

If we examine the remains of the oldest representatives of the horse in this country, we shall find that these animals were all polydactyl, and of small size. As the line was continued towards the present era, there was a gradual increase in size, and a diminution in the number of toes, until the present type of horse was produced. In view of the facts mentioned in the preceding pages, it will be profitable to trace the main line of descent in this group, from its first appearance to the present period, and note especially the changes in the number of digits. For this purpose the diagram given above will be instructive, as it records the principal stages in the series, both of the limbs and the teeth as well. This diagram was prepared by the writer for Professor Huxley, who used it first in his New York lectures. The specimens figured are all in the Yale Museum.

The original ancestor of the horse, not as yet discovered, undoubtedly had five toes on each foot. The oldest member of the group now known is the *Eohippus*, which had four well developed toes and the rudiment of another on each fore foot, and three toes behind. This animal was about as large as a fox, and its remains are from the Coryphodon beds, near the base of the Eocene. It is not represented above, as it was found since the diagram was made. In the next higher division of the Eocene, another equine genus, *Orohippus*, makes its appearance. It resembled its predecessor in size, but had only four toes in front and three behind, as shown in the lowest series of the diagram. At the top of the Eocene, a third allied genus has been found (*Epihippus*), which closely resembled *Orohippus* in its digits, but different in its teeth.

Near the base of the next formation, the Miocene, another equine mammal, *Mesohippus*, occurs. This animal was about as large as a sheep, and had three usable toes and the splint of another, on each fore foot, with but three toes behind, as shown in the diagram. At a somewhat higher horizon, a nearly allied genus, *Miohippus*, has been found, which has the splint bone of the outer or fifth digit reduced to a short remnant. In the Pliocene above, a three-toed horse (*Protohippus*), about as large as a donkey, was abundant, and still higher up a near ally of the modern horse, with only a single toe on each foot (*Pliohippus*), makes his

Fig. 4.—OUTLINE OF HORSE WITH EXTRA DIGIT ON EACH FOOT.

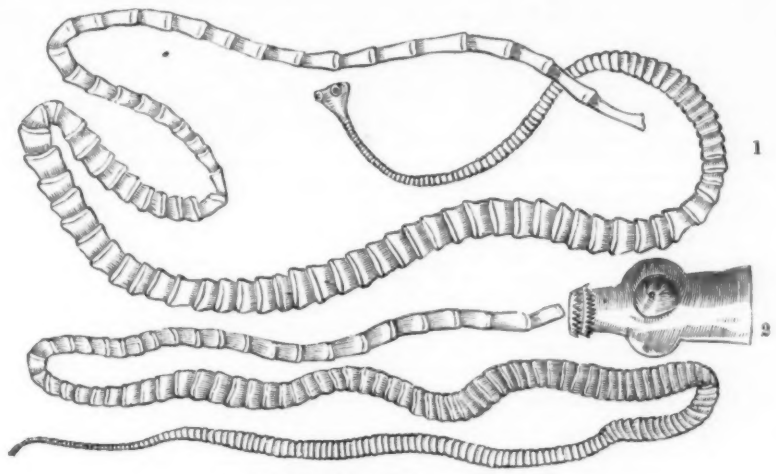
appearance. A true *Equus*, as large as the existing horse, appears just above this horizon, and the series is complete. —*American Journal of Science and Art.*

ENTOZOA.

THE entozoa, or internal worms, so called because they are all found in the systems of living animals, are a very great class. We briefly mention the Guinea worm (*Filaria medinensis*). It is one of the most developed of this group of animals. It is a strange looking creature, eight or ten feet in length, and not thicker than an ordinary sewing thread. It is found in many of the hotter parts of the world, especially in the country from which it takes its name.

The Guinea worm is much dreaded in the countries where it resides, on account of the pain and inconvenience which it occasions, and the great difficulty in destroying it. It generally takes up its residence in the leg, and there grows to an inordinate length, causing much pain and swelling until the head of the worm makes its appearance. The worm is removed by drawing it a little at a time until it is entirely drawn out. This operation takes two or three weeks and is quite simple, but demands the greatest care, as, if the worm should be broken, a most painful and even dangerous tumor is certain to arise.

The genus Tænia may be accepted as the type of all the entozoa. The well known Tape-worm (*Tænia solium*) belongs to this genus. In the illustration, which we extract from *Wood's Nat. Hist.*, the upper figure represents a species of tape-worm that is found in the common cat, and the lower figure affords an example of a tape-worm that is found in several birds. This figure shows an enlarged view of the head of the worm, with its four suctorial disks.



1. CAT-WORM.—*Tænia crassicollis.*
2. LARK-WORM.—*Tænia platycephala.*

MILU DEER.

THERE are no more deeply interesting wild inhabitants of the world than those of the numerous and greatly varied deer species. Their grace or dignity of aspect, their fleetness of foot, their flesh, always esteemed luxurious as food and peculiarly wholesome, their boldness, intelligence, etc., have ever been dwelt upon with delight. The naturalist finds no genus of animals more attractive, and even in their fossil history they display features of the greatest interest and importance. Amongst the least known species is the Milu.

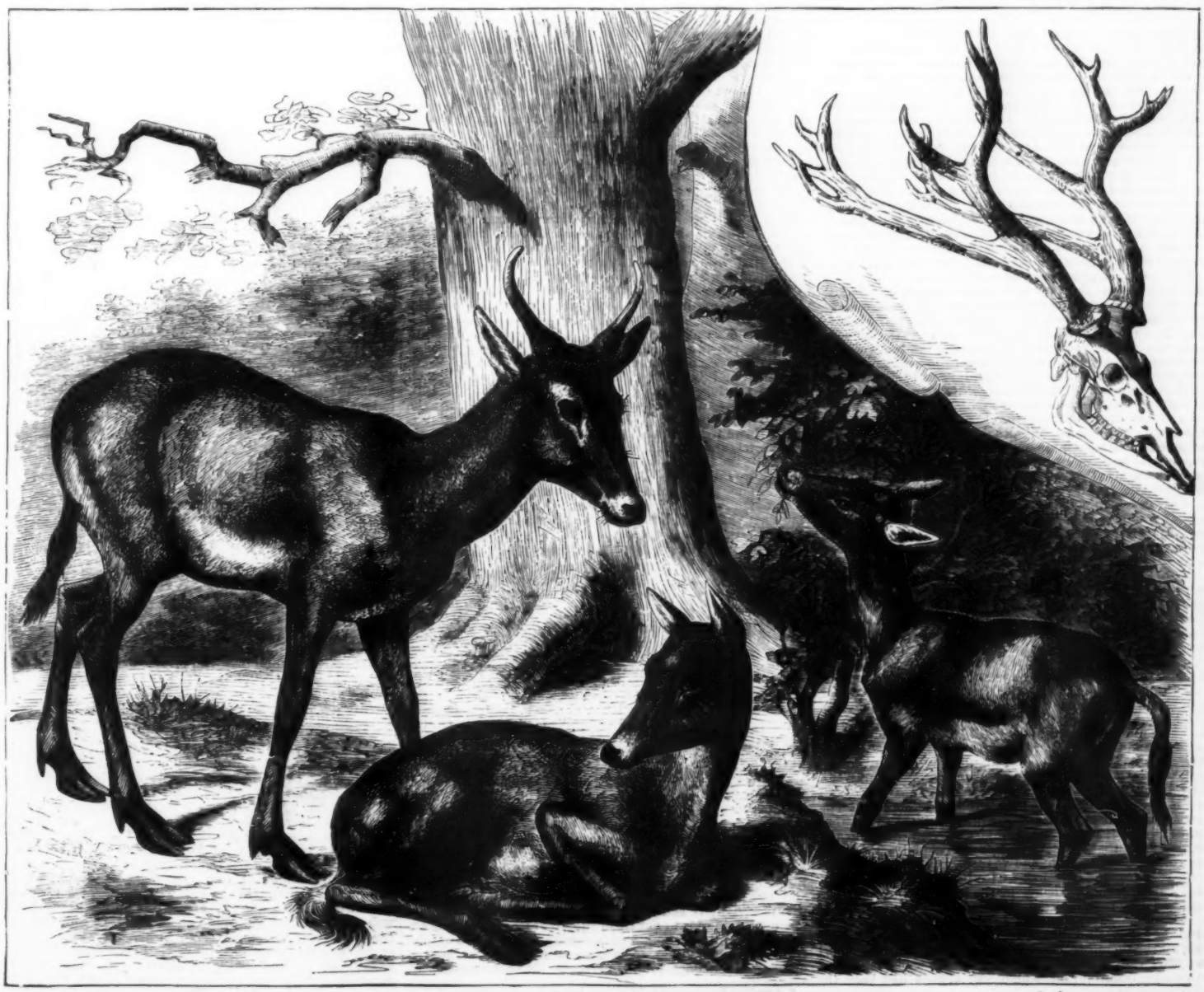
A mile south of Pekin is a large imperial park, Nan-hai-tse by name, about ten miles in circumference, and shut off from the outer world by a wall, and no unauthorized person dare venture in. Here in 1865 the missionary, Armand Davis, observed a peculiar long-tailed deer, which after some correspondence with Professor Milne Edwards was declared to be a new species, and called after the discoverer, *Elaphurus davidianus*. This animal somewhat resembles the reindeer, but differs from that animal in the bare snout, the shape of the head, and other peculiarities. The tail resembles that of the ass, and consists of bushy hair reaching down about the length of a foot. The animal is of a tolerably large shape, the grown male standing about 4 feet high, and the usual length from the snout to the tip of the tail about 7¼ feet for a full grown male.

The color of the rough and brittle hair changes with age and the seasons from a red fawn color when young to a gray, and later on in life to a yellowish tint. The head is long but narrow, the ears are small, and the tear furrows large. A special envoy from Germany to Pekin sent home three of these animals, which are now in good health at the Berlin Zoological Gardens, and of which our artist has given below a very faithful representation. Father David, the discoverer, was of opinion that the Milu deer inhabited the cold deserts of Northern Thibet.

VULCANOLOGY IN ITALY IN 1878.*

A FEW years ago Cav. Michele Rossi, brother and collaborateur of the well-known author of "Roma Sotterranea," determined to try the experiment of collecting together from all parts of Italy facts connected with vulcanology, and publishing an account of them in the form of a monthly fasciculus. He hoped by this means to found a new school for the study of endogenous meteorology, to be affiliated with the study of meteorology proper. The experiment has succeeded admirably, and we have before us a volume of 140 pages, recording all the phenomena of internal telluric dynamics which have been observed in Italy and Sicily during the past year. The vulcanology of Sicily, notably of Etna and the eastern sea-board, is also recorded in the Acts of the Accademia Gioenia of Catania. In no other part of Europe, except Iceland, would it be possible to have a journal solely devoted to the volcanic phenomena of one country. The kingdom of Italy contains within it the two most famous volcanoes in the world; it contains solfataras, soffioni, and maccalube; it is subject to earthquakes, sometimes of great severity, and spread over large areas; the district between Naples and Cape Misenum embraces almost every phase of volcanic phenomenon, excepting only the geysers, and the Stufe di Nerone belong to this class of effects. Hence, obviously, there is no country of equal accessibility in the world which is so well adapted for the study of vulcanology.

* "Bulletino del Vulcanismo Italiano. Periodico geologico ed archeologico per l'osservazione e la storia dei fenomeni endogeni nel suolo d'Italia." Redatto dal Cav. Prof. Michele Stefano de Rossi. Rome, 1878.



MILU DEER.

The Bulletino opens with a tribute to the memory of Padre Angelo Secchi, which is followed by a proposition to erect a monument to his honor. We were glad a few weeks ago to notice that a well-executed bust of the great Roman astronomer had already been placed among those of the many celebrities which adorn the Pincian Hill. The new monument will probably take the form of a *monumento meteorologico*, to be erected in Rome.

A list of twenty-six Italian observatories in which seismic observations are recorded is given in the Bulletino, with the names of the observers, who are in direct communication with Prof. de Rossi. Among the minor notices we find mention of the proposed railway to the observatory of Vesuvius; of various new seismological observatories, including that of the Solfatara at Puzzuoli; and of the earthquake which was simultaneously felt at Fiumalbo, Florence, and Rocca di Papa. Bibliographical notices and correspondence find a place at the conclusion of the fasciculus. In the next number we find letters on the application of the microphone to seismological studies, from Prof. Michele Rossi and Count Giovanni Mocenigo, and later in the volume a very interesting article by the former details his experiments on the subject. The Umbrian earthquake of September, 1878, receives full description at the hands of Prof. Arpago Ricci, Silvestri gives an account of the mud eruption which broke out on the sides of Etna, near Paternò, in December; and Palmieri continues his "Cronaca Vesuviana" to the end of September, 1878. An exact account of the time of occurrence of earthquake phenomena in any part of Italy is entered in a tabular form, and it is surprising to notice that not a day passes in Italy without some indication of endogenous dynamic action. This also proves to us the sensibility of the instruments. The date is given, then the hour, the place, and the nature of the observation, thus:

"13 —0.08 a. Messina, forte.—Reggio di Calabria, due scosso.—Palmi, scosse.—Capo Spartivento, molto forte.—Tropea, leggera ondul.

1 15 a. Corleone, leggera E—O, rombo.
5.50 a. Tolmezzo, debole; altra poco dopo.
7.15 a. Narni, sensibile N O—S E.
Mattina Rocca di Papa, leggerissima.
11.15 a. Bologna, leggerissima."

At the conclusion of the volume there is a large table showing at a glance the daily distribution of earthquakes throughout Italy Twelve vertical divisions correspond to the twelve months of the year, and these are further divided by small lines into days. The horizontal lines serve to indicate:

1 In the uppermost portion of the diagram the height of the barometer in millimeters. Thus we have the barometric curve for each month
2. Here also is shown the variations during each month of the level of the water in the wells of Leghorn and Porretta.
3. Earthquakes according to the latitude.
4. Earthquakes according to the longitude, east and west of the meridian of Rome.
5. Daily maxima of the force of the shocks.
6. Phases of the moon.
7. Daily maxima of the number of the shocks.

In Prof. Michele Rossi's seismological observatory in Rome we saw at work a set of instruments devised by himself for registering both vertical and horizontal shocks. These are not the same as Palmieri's instruments, and are said to be more sensitive. In both sets of instruments the general principle is the same. The shock, by its movement, communicates motion to some appliance, such as a pendulum, or a column of mercury in a bent tube, which establishes electrical communication with a recording instrument. In the latter a ribbon of paper is drawn at a definite rate over a drum, and whenever electrical contact is established a small electro-magnet becomes active and draws down an armature to which a pin is attached, and for every contact a mark is made upon the paper ribbon. The length of paper corresponding to an hour of time being known, it is easy to determine the instant at which the mark has been made, viz., the instant at which the shock has occurred.

Without any doubt the most interesting article in last year's Bulletino is that on the application of the microphone to the study of subterraneous meteorology, by Prof. Michele de Rossi. In 1875 Count C. Mocenigo, of Vicenza, made an observation which was nothing less than the fundamental fact of the microphone, at a time when neither microphone, phonograph, nor micro-tasimeter had been invented. He observed that electric currents indicate perturbations and interruptions in a galvanometer by means of frictions and shocks produced artificially between conductors not in perfect contact ("per effetto soltanto di attriti e di scosse communicate artificialmente ai conduttori posti fra loro in semplice contatto instabile"). He also observed that the same phenomena were produced by natural and unknown causes, when the apparatus had not received any artificial shock. The account which he gave of his observations led Prof. de Rossi to conclude that these unknown perturbations arose from microseismic oscillations of the soil. He communicated his views to Count Mocenigo, who at once commenced to make experiments in the direction indicated, in the midst of which the news of the invention of the microphone in America was received. Prof. de Rossi at once endeavored to apply it to the detection of subterranean phenomena, and for this purpose he commenced a series of experiments in the seismic observatory which he has established at Rocca di Papa, one of the Alban Hills, about seventeen miles from Rome. A special microphone, consisting of a balanced pointed lever lightly touching a plate of silver, was mounted on a stone pedestal, and was placed twenty meters under ground, at a distance from habitations and from roads. It was also thoroughly isolated and shut up in a box filled with wool. The instrument was watched during some of the stillest hours of the night, and the same mysterious sounds which Count Mocenigo had recognized were heard by De Rossi, which he considers were incontestably natural and intra-telluric. The sounds were carefully analyzed, and were compared with artificially produced sounds. The microseismic sounds were speedily differentiated from other sounds, and their nature was completely confirmed when it was observed that they were often coincident with movements of the seismograph, and that they were of a periodic character. On one occasion, as De Rossi was listening at about half-past three o'clock in the morning the telephone connected with his subterranean microphone emitted sounds like the discharge of musketry, of such loudness that he feared they would awaken a child who slept in the same room, and he therefore disconnected the telephone. A short time afterward, toward four o'clock, a sensible shock of earthquake occurred, for which the sounds had been the microphonic preparation.

In the beginning of last September Vesuvius showed many signs of an approaching eruption. During the night of the 22d of that month the mountain produced thundering sounds, and at the same time loud metallic noises were heard in the microphone, more than a hundred miles distant The microphone was soon afterward transported to the observatory on Vesuvius, and it was then possible to trace the precise correspondence between the movements of the seismographs and the sounds of the microphone, and, moreover, to ascertain the seismic value (*il significato sismico*) of the different sounds of the microphone. It was also ascertained that if a watch were connected with the microphone the noise of the tic-tac heard in the telephone became much louder just before a shock, and gradually less and less loud as the seismic agitation died away. This led Prof. de Rossi to improvise a microphone which he has found very useful for microseismic purposes.

A watch is placed upon a suitable stand, and a thin copper wire connected with the positive pole of a small battery is arranged so that one end of it, furnished with a steel needle, rests lightly upon the smooth silver surface of the watch. The handle of the watch is connected by the wire with the telephone, the other binding screw of which is connected with the negative pole.—*G. F. Rodwell, in Nature.*

[Continued from SUPPLEMENT No. 187.]

AMERICAN ENGINEERING.*—II.

BRIDGE SUPERSTRUCTURE.

THE early American bridge builders built almost entirely of wood; they found timber abundant, cheap, and good, iron was scarce and dear; and the limited amount of capital forbade the construction of masonry arches where any cheaper substitutes, even of a temporary character, could be used. They built wooden trusses to cross rivers and wooden trestles over ravines; the former to be renewed from time to time, as the timber decayed, the latter ultimately to be filled with earth embankments.

While the earlier truss bridges were of experimental character and of many different designs, two forms soon took a prominent place as the most common and probably the best wooden bridges; these were known as the Burr bridge and the Towne lattice. The Burr bridge was built of square timber; the chords were made of two timbers placed side by side; vertical pieces were placed about ten feet apart and framed through the chords, projecting sufficiently, above and below, to form a connection which would resist tension, and diagonal struts were framed into these verticals between the chords. The Towne lattice was built entirely of plank, usually three or four inches thick, all the connections being made by wooden pins driven through auger holes, the arrangement of parts being generally similar to those of an iron lattice. Both of these bridges did good service, and they are still used for highway bridges in rural districts. They were usually completely covered in, and frequently strengthened by timber arches springing from the masonry several feet below the trusses, to which they were fastened at frequent intervals. Good examples of these bridges, built as early as the beginning of the century, are still standing.

Another wooden bridge of somewhat later date, but which was built very largely about twenty years ago, was the MaCallum truss. It was in reality a modification of the Burr, the peculiarities being in the upper chord, which was always curved so as to increase the depth of the truss at the center, and in the use of the so-called arch braces, which starting from the masonry passed through the lower chord and terminated at different panel points in the upper chord. It was the boast of the inventor that these braces would sustain the bridge even if the lower chord were cut in two, and an instance actually occurred in which the entire lower chord and floor fell under the weight of a train into the river, and the upper portions of the truss were left standing. This bridge was exceedingly stiff, and for a time very popular, but it was so complicated that it was customary to make a full-sized drawing on a smooth floor, from which patterns were taken for the framers. It has gone out of use.

The first real advance from the old wooden trusses was made about forty years ago, when iron rods were introduced to take the tensile strains of the web. This was accomplished in two different trusses, the Pratt truss, in which the web was composed of vertical timber compression members with diagonal rods for ties, and the Howe truss, in which the rods were vertical and the diagonals were wooden struts, one system of bracing being precisely the reverse of the other, and both furnishing the opportunity for perfect counter bracing, in which the Burr bridge was deficient, and which was a necessity in railroad bridges. At first the two systems appeared of equal merit, but the vertical rods of the Howe required a minimum amount of the more costly material, and afforded special advantages for simplicity of detail; on the other hand, it was found difficult to keep the two iron diagonals of the Pratt truss in proper adjustment. The Howe soon took the place which it still holds, as the standard wooden truss, while it was left for the iron construction of a later period to appreciate the real merits of the Pratt.

THE HOWE TRUSS BRIDGE.

The Howe truss may justly be termed the most perfect wooden bridge ever built; others have been designed of greater theoretical economy; but for simplicity of construction, rapidity of erection, and general utility it stands without a rival. As usually built, the chords are made up of three to five sticks of timber, 10 to 14 inches deep, and 6 to 8 inches wide. They are placed about an inch apart, the lengths breaking joints, and are fastened together at intervals of about 4 feet with iron bolts and wooden keys, the latter being blocks 2 inches thick, which are let into the timber half an inch; in the lower chords the joints in each line of timber are coupled with wooden clamps. On the chords (above the lower and below the upper) rest the cast iron angle blocks; these are castings as long as the chord is wide, and of triangular section, two surfaces serve as skewbacks for the diagonal braces to rest upon, and the third surface, which comes against the chord, has a lip cast upon it which, fitting into a groove cut across the chord, serves to transmit the strain from the block to the chord. The angle block is cast with two or more holes, through which pass the vertical rods; these are simply straight rods of round bar iron, with a screw cut on each end; they pass through the chords, between the different lines of timbers, and the nuts screw up against washer plates of wrought iron placed above and below the chords. The only framing about the braces is to cut them square to length, and the entire truss can be laid out with a square and scratch-awl, and framed with no other tools than a saw, an adze, and an auger. When once properly erected, the only attention required is an occasional adjustment of the nuts so as to preserve an equal strain in the rods of each set.

Mr. Howe built his first bridge, a single highway span of 75 feet, in 1840; his second bridge was a railroad bridge of seven spans of 180 feet each across the Connecticut river at Springfield, built in the same year. The lower chord was made of planks packed close together with oak treenails; the panels were only seven feet long and the braces reached across two panels; the braces were all of the same size, as were also the vertical rods; the angle blocks were of wood. This bridge, though light and badly proportioned, lasted till 1853, when it was replaced by a Howe truss of more modern design, which was still in fair condition in 1874, when it was replaced by a double-track wrought-iron structure.

The Howe and Pratt trusses, as originally built, were empirical structures like their predecessors; they were proportioned by imperfect rules and without calculation. The simplicity of their design, however, offered inducements for analysis, and the analytical methods now used by American engineers in building iron bridges were applied by the best builders to these more crude structures.

INTRODUCTION OF IRON BRIDGES.

The Howe and Pratt trusses introduced the use of iron for the lightest portions of the truss; the next advance was to make the entire truss of iron. The general plans of the wooden bridges were adhered to as far as they were applicable to the new material; the bottom chords, strained in tension, were made of wrought iron bars, and the compression members were of cast iron. The bars of the lower chord were joined together with eyes and pins, and the upper chord was cast in panel lengths with square bearings; the rods of the web usually passed around the pins of the lower chord, while the connection at the upper end was by nut and screw. The first successful iron bridges were those designed by Squire Whipple, many of the earliest of which are still standing, their skeleton being substantially the same as that still in most common use: a Pratt truss with the end posts inclined so as to reach over the first panel.

The adjustable truss with cast iron compression members was the real beginning of iron bridge building in America. A large number of bridges of this sort have been built even to a late period by Mr. Francis C. Lowthorp, in which all tensile connections are made with screws.

Up to the year 1850 few iron bridges had, however, been constructed of longer spans than 50 feet.

The first impulse to the general adoption of iron for railroad bridges was given by Mr. Benj. H. Latrobe, Chief Engineer of the Baltimore and Ohio Railroad. When the extension of this road from Cumberland to Wheeling was begun he decided to use this material in all the new bridges. Mr. Latrobe had previously much experience in the construction of wooden bridges in which iron was extensively used; he had also designed and used the fish-bellied girder, constructed of cast and wrought iron, and which is still in use on the Baltimore and Ohio Railroad; he had adopted on the older portion of that road the Bollman plan of bridge for short spans, which has since come into extensive use. But for the general plan of bridges west of Cumberland he adopted the plans submitted by Mr. Albert Fink, his assistant.

The basis of this system was the trussed girder, the straight beam with a single post at the center, supported by inclined rods reaching to each end. Mr. Fink increased the practical length of this style of truss by making each half a secondary trussed girder, and then by treating the quarters and subsequently the eighths in the same way, he extended the single principle of the trussed girder to a truss of sixteen panels; the same upper chord acted as the beam for all the systems, but otherwise they were independent.

In both the Fink and Bollman trusses all parts were suspended from the upper chord, and no lower chord was required; they were distinguished by the name of suspension trusses. One of the earliest examples of the Fink truss is the bridge over the Monongahela River, on the Baltimore and Ohio Railroad, completed in 1853, and still in use. The chords and posts were of cast iron, and the tension members of wrought iron. The bridge consists of three spans, each of 205 feet length, the longest then constructed in this country. All the bridges on the Baltimore and Ohio Railroad were built upon this general plan, and it was adopted on many roads in the South. In many bridges wood was substituted for the cast iron in the parts which resist compression, and this combination resulted in a structure which combined durability with great cheapness. It may be proper to mention here that this plan of truss was particularly designed with the view of making it self-adjustable, when two materials are combined in it, which are differently affected by change in temperature.

While this development in the construction of iron bridges was going on quietly in the more Southern States, during the years from 1850 to 1860, very few iron bridges were then built in the Northern States. The reason for this delay in the adoption of iron for bridge construction must be found in the general prejudice which then existed in the mind of the public, shared even by many engineers, which had been caused by the failure of a badly proportioned iron bridge on the New York and Erie Railway in 1850, and also by the failure of the iron bridge over the River Dee, in England, which took place about the same time. It was difficult for the few engineers, who combated the crystallization theory which was then advanced, to overcome this prejudice. It was some ten years after the commencement of the earlier efforts to which reference has just been made that iron bridges were introduced on the Pennsylvania Railroad, upon the plans of Mr. J. H. Linville. The best of these earlier examples is the bridge over the Ohio River, at Steubenville, which was built in 1863, with a span of 320 feet.

About the year 1867 iron bridge building in America began to assume its present importance. In this year the first iron bridges over the Mississippi were begun, and the scheme for the great bridge at St. Louis began to assume a definite form. At this time the most prominent designs for iron bridges were of four kinds. The Fink and Bollman suspension trusses, the Pratt truss, and the Warren girder. The Howe truss had been built in iron to a limited extent, but it was soon found that, however excellent in wood, it was poorly adapted to iron construction. In order to obtain greater economy in the web without the use of panels of unusual length, the Pratt truss was built with a double web system (called the Whipple, Murphy, or sometimes the Linville truss), and the Warren girder was either doubled or the floor was suspended by vertical rods from the intersections of the braces with the upper chord. Cast iron was generally used for compression members, which were cast of hollow cylindrical form. Mr. Linville, President of the Keystone Bridge Company, had, however, built bridges with wrought iron posts, and the hollow wrought iron

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* American Engineering as illustrated by the American Society of Civil Engineers at the Paris Exhibition of 1878. Compiled by George S. Morrison, Edward P. North, and John Bogart, Committee, Transactions of the Amer. Soc, of Civil Engineers.

riveted column made by the Phœnix Iron Company had already been received with much favor. Many builders, however, preferred to retain the cast iron top chord, while using the wrought iron posts in the web.

Shortly before this Mr. S. S. Post had designed and patented the Post truss. The details of this bridge were in many respects novel, but the distinctive feature was the arrangement of the posts and ties of the web; the bridge being usually built with a double web system, and the posts being given an inclination across half a panel, main ties across a panel and a half, and the counter ties the same inclination as the posts reversed. This design was the result of careful calculations, and thought to be very economical.

About this time, also, the use of combination bridges became common—this term being applied to bridges in which the lower chord and other tensile members were of wrought iron, the top chord and compression members being wood. The origin of this system of construction may, perhaps, be found in the early suspension trusses of Mr. Fink, with wooden chords and posts. Mr. Fink also introduced what was known as the V combination truss, a Warren girder with top chord and braces of wood, and lower chord and ties of wrought iron; this bridge was easily protected from decay by covering the upper chord and principal braces with a tinned roof; it is, probably, the best combination bridge built, and is used largely in many parts of the South, where it has virtually superseded the Howe truss. The Post truss was often built as a combination truss, and the Pratt truss is still built in this way. The first bridge across the Missouri river, built in 1867–69, at Kansas City, by Mr. Chanute, was an example of a combination double system Warren girder, with curved upper chord.

The introduction of wrought iron posts was soon followed by the use of the same material in the heavy compression sections of the top chord, and the best builders were not slow to realize that the screw adjustments which were important in wooden bridges were of no advantage in an iron structure; the screw connections at the upper ends of the tension rods were accordingly dispensed with, and bridges built with pin connections throughout. The use of cast iron has gradually become less and less, until now many engineers have entirely dispensed with it, making all the connections and details entirely of wrought iron.

The peculiarities of American iron bridges, as compared with those of the European builders, may be traced in no small measure to the fact that in America the construction of wooden bridges was practically perfected before the building of iron bridges was begun. Many of the features of wooden construction were repeated in iron, sometimes with very unsatisfactory results, and only to be abandoned as the builders became more proficient; but the most prominent feature of American bridge design is the concentration of the material in a few members, and this was realized in the Pratt, Howe, and other trusses, before iron bridges were built. Simplicity of skeleton form has been followed from the first; and since the use of wrought iron track stringers has removed the objections to long panels, single systems of bracing have generally been preferred to double, and the simple Pratt truss, of wrought iron with inclined end posts, and all tensile connections made with iron bars and pins, has of late years been built more largely than any other design.

The European systems, on the other hand, have not been without their advocates; riveted structures, copied originally from foreign designs, were early introduced on the New York Central Railroad and some of its connections, and this has ever since been the standard system of construction on those lines. The earlier bridges were generally built with vertical compression members and inclined ties; the latter being so numerous as to give the structure the appearance of a lattice bridge. For the shortest spans riveted plate girders were used. The system of construction has not been without its influence on the designs which are considered more strictly American, and its development has undoubtedly been modified by the standards of other builders. Plate girders and trellis bridges, built of plates and angle irons, have now become the favorite forms of iron construction for spans of 60 feet and under, and their use is yearly becoming more common. On the other hand, in trusses of greater length, the builders of riveted work have departed from the European forms of construction and concentrated their material in comparatively few members, the usual design being a species of lattice in which the parts are so few that each diagonal is intersected by only three others—the truss being, in fact, a four-system Warren girder, in designing which the strains of each member are separately calculated in much the same way as is done in the more widely separated members of a pin-jointed truss. One of the best examples of riveted bridges was built in 1874, over the Connecticut river, at Springfield, Mass., on the piers once occupied by the first Howe truss that ever carried a railroad.

In the early building of railroads, and even of late years in the construction of lines in timbered or thinly settled districts, the use of wooden trestle work played a part hardly inferior in importance to that of wooden truss bridges. The plan of trestle work commonly adopted consisted of bents placed from 12 to 18 feet apart, each bent consisting of a sill, four posts and a cap, all of timber 12 inches square; the sill rested on piles or sub-sills, according to nature of the foundation; the two inside posts were vertical and placed directly under the rails, and the outside posts were given a batter of about 1 in 4; the posts were framed into the sill and plate with mortise and tenon, and the bent was stiffened by diagonal planks bolted or spiked on each side. Stringers resting on the caps connected the several bents, and on them were laid the ties to which the rails were spiked. This trestle, with very slight modifications, has been built in all parts of the country, and used to carry railroads across ravines where the cost of earth embankments was too great for the economical demands made on the engineer. Where the height exceeded about 20 feet the bents were built in two or more stories, an intermediate cap with light longitudinal stringers being placed at the top of each story. For structures of great magnitude special designs were followed, in the best of which the use of mortise and tenon was abandoned, and the different lengths of timber were made with square butt joints resting directly upon one another. The best known example of this class of structure was the great Portage viaduct designed by Mr. Silas Seymour in 1851, which was so arranged that every timber could be taken out and replaced without disturbing the stability of the structure.

The first examples of iron trestles were erected in 1853 by Mr. Fink on the Baltimore and Ohio Railroad. There are two of these trestles or viaducts crossing ravines on Cheat river, at an elevation of 250 feet above that river. They are located on grades of 1 in 50, and one of them on a curve of 800 feet radius, and are built entirely of cast iron. The trestle is 60 feet high; the posts are cast in two sections; the lower has a diameter of 7 inches, and the upper of 6½ inches, with ¾-inch thickness of metal. Every 25 feet there is a vertical post, from the foot of which two inclined braces start; the braces in the several panels meet at the top in the center of the 25 foot space, giving a support to the stringers bearing the track, every 12½ feet. The length of these trestles is 500 feet, and they are built in sections of 125 feet length; each section is braced together in such a manner as to permit it to slide—from the center each way—upon the foundation plates, in order to permit of the contraction and extension of the structure under the influence of changes in temperature.

These structures, presenting an extremely light appearance, have now been in use for 25 years, and may, perhaps be considered the boldest attempt in the use of cast iron in bridge construction.

About a dozen years ago Mr. C. Shaler Smith began building wrought iron trestles, using Phœnix riveted columns for posts, each bent consisting of two posts with cross struts at intervals of about 30 feet, and diagonal tie rods, the bents being placed 30 feet apart, supporting trussed girders, and stiffened longitudinally by struts and diagonal ties; these trestles were built at first with all longitudinal members of wood so as to avoid any difficulties from thermal expansion, but by omitting the struts in every third or fourth span there was found no difficulty in making all parts of iron. This general system of construction has now become very common, and iron viaducts of skeleton design are built by all bridge builders, the designs being more or less varied to suit the peculiar requirements of each case. In all of these, however, the same prevailing characteristic is found that marks the truss bridges, the concentration of material in a few members, and the economical advantages of this system are found even greater in lofty viaducts than in long span trusses. The most remarkable example of iron viaducts is the bridge lately built by Mr. Smith across the Kentucky river, consisting of three spans, each 375 feet long, which rest upon iron towers, and carry a railroad at a height of 275 feet above the river.

As early as 1847 Squire Whipple printed with his own hands a memoir on the strains in skeleton structures, in which the general principles of calculating strains and proportioning the parts of the more common forms of trusses were correctly enunciated. This memoir was the foundation of American scientific bridge building. The practice of American bridge builders is to calculate in detail the strains on each separate member of a truss, preparing strain sheets or skeleton diagrams on each line in which the estimated maximum strains are marked; in common practice railroad bridges are designed to carry 3,000 pounds for each foot of track, with an additional allowance to cover the extreme strains produced by a heavy locomotive on the floor and web systems; it is not unusual, however, to calculate the effects of an actual train, considering the different weights on the wheels. The pin joint system offers the best assurance that the actual strains will agree with the calculations, and renders simple the connection of large sized members, whose use in riveted structures is virtually excluded by the large number of rivets required in the joints.

The practice has been to build the several members of a bridge in the shop, finishing every part. The tensile members are eye bars with forged heads and eyes drilled to fit accurately on turned pins; the compression members are usually built of plates, angles, and channel irons, or of special shapes like the sections of the Phœnix column. Each member is complete as it leaves the shop, and the bridge has only to be put together at its site, little or no riveting being done there; a span of ordinary length will be erected in two or three days.

The last ten years have witnessed the erection of structures of a magnitude which had not been attempted in America till then. The Raritan drawbridge, which turns on a central pier and has a total length of 472 feet, and the channel span of the new bridge over the Ohio at Cincinnati, 520 feet long, both designed by Mr. Linville and built by the Keystone Bridge Company; the Rock Island drawbridge, designed by Mr. C. Shaler Smith, and weighing 750 tons; besides the drawbridges, all over 360 feet long, on the Mississippi, and four other bridges across the Ohio, with channel spans from 350 to 400 feet, are examples of the application of the more usual forms of construction of works of unusual size. The St. Louis bridge, with its three spans of steel-ribbed arches each, about 500 feet long; the stiffened suspension bridge at Pittsburg, and the great steel wire suspension bridge at New York, with a clear span of 1,600 feet, the cables of which are now in position, are prominent cases in which the engineers have thought best to depart from the usual forms of truss construction and to erect structures specially designed to meet the peculiar requirements of each case.

THE OLD AND NEW VIADUCTS OF PORTAGE, NEW YORK.

SILAS SEYMOUR, Engineer of Old Viaduct. GEO. S. MORISON, Engineer of New Viaduct.

The original Portage bridge was the most remarkable timber viaduct ever erected. It was begun July 1st, 1851, and completed, so as to cross with an engine, on August 14th, 1852. The viaduct was over 800 feet long, and 234 feet high from bed of the river to the rail, the masonry being 30 feet high, the trestles 190 and the trusses 14 feet. It contained 1,602,000 feet B. M. of timber, 108,862 lb. of iron in bolts, and 9,200 cubic yards of masonry. Three trestles were grouped together forming a timber pier, and it is estimated that a single one of these piers would sustain 3,000 tons besides the weight of the structure. These piers were fifty feet apart. The general plan was made by Silas Seymour, Chief Engineer, and the drawings and bills of material prepared by H. C. Brundage.

On Thursday, May 6th, 1875, this timber viaduct was destroyed by fire. The destruction of everything above the masonry was complete.

THE NEW BRIDGE.

On Monday, May 10th, the contract for the iron work was let to the Watson Manufacturing Company, of Paterson, the bridge to be built according to plans of George S. Morison, C. E. The first iron column was raised June 13th. On July 29th, the iron was all in position; on the following day the track was laid across, and on Saturday, July 31st, the bridge was tested and thrown open for traffic.

The main principle of the plan may be said to be that which characterizes all American bridge building, and is the leading difference between the works of American and European engineers—the concentration of the material into the least possible number of parts.

The iron viaduct has 10 spans of 50 feet, two of 100 feet, and one of 118 feet, a 50 foot span being placed between each of the long spans. The trusses are supported by wrought iron columns, the ends of two adjacent trusses resting upon a single column. The pair of columns supporting the opposite trusses are in the same vertical plane, but are inclined towards each other and connected with wrought iron struts 25 feet apart and diagonal tie rods, thus forming a two post bent; each column is connected with the parallel column of the adjoining bent by a similar arrangement of struts and diagonal ties; four columns with the connecting bracing are thus made to form a skeleton tower 20 feet wide and 50 feet long on the top, surmounted by a fifty foot span of bridge, having the same length at the bottom and a width varying with the height of the tower. There are six of these towers, the largest having a total height from masonry to rail of 203 feet 8 inches.

The trusses of the superstructure are proportioned to carry a moving load of 3,000 pounds per running foot, and an excessive load of 5,000 pounds per foot, with a maximum tensile strain of 10,000 pounds per square inch. The towers are built to carry a moving load of 5,400 pounds per running foot (being designed for two tracks); they are also calculated to resist a wind pressure at right angles to the bridge, of 30 pounds per square foot, exerted on the entire surface of the structure and of a train of cars, and one of 50 pounds per square foot exerted on the surface of the structure alone.

The columns rest upon cast iron pedestals, those on the north side of the bridge being secured by dowels to a cast iron plate sunk in the masonry, and those on the south side being placed on rollers, rolling at right angles to the axis of the bridge. The columns are made in 25 foot lengths. They are formed of three plates and four angle irons, with a lacing on the fourth side, so that the interior of the column is accessible for painting. The angles are all 4 × 4 × ½ inches, and the plates are all 16 inches wide; the thickness of the side plates being varied to provide for the increased strains in the lower sections. The ends of the several lengths are squared and faced, and they rest directly upon one another without joint boxes; the upper end of each length is fitted with two projecting plates which form a tenon; the length above fits over the tenon plates and is secured to the lower length by a turned pin of 1⅜ inch diameter passing through carefully bored holes; the same pin serves for the attachment of the longitudinal rods. A second pin, at right angle to this one forms the attachment for the transverse strut and ties. The diagonal ties are everywhere in pairs. The longitudinal strut, which is nearly fifty feet long, is built in the form of a light lattice truss, is two feet deep and one foot wide, with the ends squared and butting against the side of the column.

The towers were raised with no other false work than that actually used in handling the material of each successive section. Before beginning to raise a tower, a floor of long timbers reaching from pier to pier and loose boards was laid at the site of the tower; on this floor was erected a framework 30 feet high, and composed of two bents, one on each side of the tower; each bent consisted simply of two posts 48 feet apart and a cap 55 feet long, braced with planks across the corners. The lower lengths of the columns were then lifted into position; the transverse and longitudinal struts put in place, and the diagonal ties put on. A gin pole 55 feet high was then lashed to each column, and these gin poles were used to transfer the floor and frame to the top of the now completed lower section of tower. The same operation was then repeated with the second lengths of columns, which were placed over the tenon plates of the lower length, and secured by the pins. When the second section of the tower was completed, the frame was used to raise the gin poles; the floor and frame were then raised again, and the process repeated till the tower attained its full height. The last tower raised, weighing 277,000 pounds, was entirely erected in 11 days, one day only having been previously spent in preparing the staging for the first section.

To erect the long spans, combination Pratt trusses were built, the top chords of which were made of four pieces of pine 4 × 10 inches, packed in pairs, and sprung about 4 feet apart in the center; the bottom chord was of straight parallel eye bars and the posts V shaped; the form of the top chord made the truss stiff without lateral bracing. These trusses were put together below, and raised by block and falls to the bottom of the upper section of the towers, where they were placed, resting upon the transverse struts, two being used for each span. A suitable staging was then erected on them, and the permanent truss was put together, the materials being run out from the end of the bridge.

The trusses are of the simple Pratt pattern. One end of each long truss is bolted to the iron capital of the column and the other is placed on rollers, but connected with the next truss by iron loops passing over the end pins of each span, and allowing only the amount of motion needed for expansion. The short spans over the truss are bolted to the capitals at both ends. The end pins of the 50 foot spans are placed 6 inches from the center of the column, and those of the long spans only 3 inches, so that under a full load the center of weight comes directly in the line of the center of the column.

The total weight of iron in the bridge is 1,310,000 pounds, divided as follows:

Towers		897,550
10 spans, 50 feet each	197,420	
2 " 100 " "	128,910	
1 " 118 " "	86,120	
Total weight of superstructure		412,450
Total		1,310,000

The amount of timber in the floor, foot-ways, and railing is 112,318 feet of oak and 18,300 feet of pine (B. M.), while 27,987 pounds of iron were used in bolts and washers, the heavier bolts being all bolts taken from the ruins of the old bridge.

BRIDGES BUILT BY DELAWARE BRIDGE CO.

CHARLES MACDONALD, C. E., President.

PASSAIC DRAW BRIDGE.

This is a wrought iron double track structure, crossing the Passaic River at Newark, on the line of the Morris and Essex Railroad. There are three trusses, sustaining the tracks upon iron beams suspended from the lower chords.

General Dimensions.

Length of trusses from center to center of end pins	220 ft. 6 in.
Height of trusses from center to center of chords	22 ft.
Width of bridge from center to center of outer trusses	30 ft.
Height of rail above the water	45 ft.

Weights adopted for Calculation.

Dead load per lineal foot of bridge	2,000 lb.
Live load, per lineal foot, covering both tracks throughout entire length	5,000 lb.
Live load, per lineal foot, covering both tracks for one-half the span	7,000 lb.

When the bridge is open all the dead load is transmitted to the central support, and the strains are determined as in the case of a beam supported in the middle. When the bridge is shut and the wedges adjusted, the extremities are brought to rest only, and the strains due to dead load are not materially changed. The effects produced by the rolling loads are now determined under the assumption that the bridge is supported at the center and extremities; and finally, the maximum strains are obtained by adding the strains due to fixed and rolling loads with their proper sign.

Weight of Iron in the Structure.

Upper chords	45,000 lb.
Lower chords	52,000 "
Posts	65,780 "
Diagonal bars	48,800 "
Pins	5,900 "
Upper lateral system	15,800 "
Lower lateral system	4,800 "
Portals	2,600 "
Cross floor beams	68,970 "
Longitudinal floor beams	41,120 "
Weight of iron in trusses	350,770 lb.
Weight of iron in turn-table	107,690 "
Total	458,460 lb.

The trusses are of the "Whipple" type, with the end posts inclined, and with two inclined posts and a vertical at the central point of support. The chords are, for the most part, made up of two 10-inch channels and a cover plate on one side, with open lattice work on the other, forming a trough shaped section. In the center panels of the upper chord, where tension alone exists, eye bars are used; all other connections in the chords are designed to resist both tension and compression. The lower chords of the center truss abut against a casting which forms the upper portion of the turn-table, and are secured to it by angle iron lugs. The lower chords and central posts of the outer trusses are riveted at their intersection to splice plates, making a continuous wrought iron connection. The connections at the abutment ends are also riveted. Vertical posts are made up of channels latticed on both sides, forming a rectangular section open on both sides to inspection. The ends are re-enforced, and pin holes bored for connection with the chords. No joint boxes are used.

The dead weight of the bridge is transmitted to the revolving surface of the turn-table through the casting at the center of the lower chord of the middle truss; that portion is borne by the middle truss directly, while the outer trusses rest upon the extremities of two plate girders connected on each side the center by diaphragm plates and lugs; by this means the entire weight of the outer trusses and cross-girders may be suspended upon twelve vertical bolts passing through holes in the sides of the central casting. This casting rests upon conical steel rollers inclosed between steel rings grooved to fit the coning of the rolls, and having half an inch play between; upon these rollers the bridge revolves. The lower ring is fitted to a cast iron seat having a hemispherical cavity on the under side to receive a corresponding cast bearing block which distributes the weight upon a wrought iron pintle extending to the masonry. Under each end of the cross girders are four trailing wheels adjusted so as to bear lightly upon the track. When one line of rails is loaded, these wheels sustain a portion of the weight, but not when the bridge is turning.

Attached to the lower side of the base girders forming the ends of the bridge, are castings containing movable wedges having one and a half inches vertical play; they are beveled to fit bed castings attached to piers so that when they are driven to a bearing, horizontal displacement becomes impossible. The free ends of the track are lifted simultaneously with the wedge movement.

The bridge may be operated either by steam or by hand, as desired. A double cylinder engine drives a vertical shaft to which are attached two friction clutches. By throwing the upper one into gear a horizontal line of shafting is made to actuate the wedges and rail lifters. By shifting to the lower friction, motion is communicated to a driving pinion working into cast toothed segments which are bolted to the masonry through the track.

A vertical shaft, for working by hand, is placed between the rails; it communicates with the wedge gear by a chain wheel, and with the driving pinion by a small intermediate.

The time required to withdraw the wedges and swing the bridge does not exceed two minutes.

This structure was erected in place of an old wooden bridge, during the winter of 1876–77, and the traffic of the railroad was not seriously interrupted during the progress of the work.

OAK ORCHARD VIADUCT.

A single track wrought iron structure on the line of the Rome, Watertown and Ogdensburg Railroad, near Rochester, New York.

General Dimensions.

Total length between abutments	690 feet.
Twenty-three spans, each	30 "
Height of trusses	9 "
Width of bridge, center to center of chords	10 "
Height of rail above the water	80 "

Weights adopted for Calculation.

Dead load per lineal foot	500 pounds.
Rolling load consolidation engine in a length of 50 feet	150,000 "

Weight of Iron in the Structure.

One span of 30 feet	7,000 pounds.
One bent 75 feet high	12,000 "
Total weight in the entire viaduct	365,000 "

In general type it resembles similar structures in other parts of the country, and is an economical distribution of material for crossing ravines. The principal bents are 75 feet in height from masonry to base of rail; they are framed in two lengths and spliced on the ground by riveting cover plates through the flanges of the channels. All the connections at these splices are of wrought iron. The main posts are made up of two 10-inch channels latticed at each flange and entirely open and accessible to painting and inspection. Base castings are anchored to the masonry to obviate the necessity of a horizontal strut at the foot of the bents. The 30-foot spans consist of plate girders 20 inches deep trussed by a center post, and eye-bars. The tension transmitted through these bars is applied to the web of the girder at a point below the center, with a view of counteracting the bending effect produced by the driving wheels of a locomotive on a half span. Changes due to temperature are provided for by firmly bracing each alternate pair of bents and connecting the 30-foot span between them with the caps of the posts, thus forming a horizontal strut and constituting with the two bents a rigid pier entirely independent of the rest of the structure. The 30-foot spans between each of these piers are attached to post caps by bolts passing through slotted holes, allowing ¾ inch play.

The time expended in the erection of the structure was three weeks. The iron was delivered at the bottom of the ravine and lifted into place by means of a movable projecting derrick.

ROCKVILLE BRIDGE.

A double track wrought iron structure crossing the Susquehanna River five miles above Harrisburg, Pa., on the line of the Pennsylvania Railroad.

General Dimensions.

Total length between abutments	3,675 ft.
21 spans	156 ft. 6½ in.
2 spans	151 ft. ½ in.
Height of trusses center to center of chords	19 ft. 7 in.
Number of trusses per span	3
Width of bridge center to center of outer trusses	22 ft.
Height of rail above the water	45 ft.
Angle of skew	68°

Weights adopted for Calculation.

Dead load per lineal foot	2,750 lb.
Rolling load per lineal foot	6,000 "

In the determination of maximum strain in the upper chords, it was assumed that the bending effect due to excess of locomotive weight was added to the direct compression.

Weight of Iron used in the Structure.

For one span of 156 feet 6½ inches.

Upper chords	100,790 pounds.
Lower chords	57,930 "
Vertical end posts	8,770 "
Inclined posts	45,290 "
Counter braced diagonals	12,670 "
Diagonal tension bars	12,670 "
Sub-posts	8,030 "
Pins and nuts	6,750 "
Lateral struts	15,030 "
Lateral rods	7,000 "
Lateral bolts and nuts	1,850 "
Wind bracing	5,400 "
Shoes at feet of end posts	2,450 "
Bed plates	1,200 "
Expansion rollers	670 "
Total iron in one span	289,500 "
Total iron in the bridge	6,670,000 "

There are three trusses in each span, with the tracks so disposed upon them as to bring an equal distribution of load upon each.

The top chords are of 12-inch channels, with thickening plates, covers upon the top and the lower side latticed. The web consists of a double system of main post and tension bars, inclined at an angle of 45 degrees, and connected at their intersection midway between the chords, by pins. At their intersection with the chords they are also connected by pins, dividing the spans into eight main panels of 19 feet 6 inches each. From the middle intersection of the web members a vertical sub-post extends to the under side of the upper chord, forming a support for that member half way between the main panel points. The chord splice occurs at this point, and at each splice the ends abut squarely, and cover plates are riveted on to insure a continuous member. The braces are built of channels, latticed on two sides, forming a rectangular section, accessible to inspection on all sides; the ends are re enforced, and they are bored for upper, middle, and lower pin connections. Where tension only occurs, eye-bars are used, instead of latticed channels. Bottom chords are made of eye-bars, in panel lengths of 19 feet 6 inches, disposed both inside and without the jaws of the braces, so as to insure a uniform distribution of strain upon each eye-bar in a panel.

Lateral struts and rods are attached directly to the pins by U-shaped nuts and a vertical bolt, no cast iron being used.

The rails are laid upon cross timbers of oak, 7 × 14 inches, spaced 21 inches, center to center, and resting directly upon the top chords, which were proportioned to resist this extra bending strain.

This structure was built to replace a wooden bridge constructed upon the general type known as the Howe truss. The terms of the contract required that the new bridge should be erected without interfering with the traffic of the railroad, or in any way endangering the stability of the old structure until the trains were transferred to the new; after that the old material was to be taken apart and placed upon trains for removal. On the 24th of May, 1877, the Delaware Bridge Company signed a contract with the Pennsylvania Railroad Company, for furnishing the material, and the completion of the structure by the 1st of December of the same year. On the 11th of August the first span was in place; and on the 18th of November following, the last span was completed, and regular traffic began over the entire length of the new bridge. The erection began at the middle of the bridge, and was continued simultaneously, with but few delays, to the two extremities. Two movable derricks served to place the iron in position, and afterwards to take down and load the old material. During the progress of the work, the average number of trains passing over the bridge per day was sixty-four, and no interruption of traffic occurred.

TRANSMISSION OF POWER TO A DISTANCE.

Although it is now at least seventy-seven years since Brahmah proposed to transmit power to great distances by means of water under pressure, and although it is half a century since Mann proposed and described the means for transmitting power over still greater distances by means of compressed air, it cannot be said that either of these means of transmission has been employed to the extent that their proposers expected they would be, nor to the extent to which they might profitably have been used in many countries. Telodynamic transmission has been employed to a considerable extent; but in several cases works erected for this purpose have been abandoned, as for instance, at Bellegarde. The loss of power in transmission by these methods is probably less by the telodynamic than by the others, but although M. Hirn, who has taken so prominent a part in bringing this method before the world, has upon reliable data calculated that this loss would be but about ten per cent. for distances not greater than twelve miles, there are sufficient reasons for saying that two or three miles is the greatest distance to which the system is practically applicable. One of the strongest objections to it is the great cost of the way works, while those which may be raised against the employment outdoors of great lengths of wire rope moving at high velocity are hardly less cogent. Hydrodynamic transmission comes perhaps next in order of economy, but this quality decreases rapidly as the power to be transmitted increases. For comparatively small powers the system is applicable, because only small quantities of water, but under high pressures, are sufficient. For large powers, however, the system loses its economy. Large mains are needed, and for the very high pressures necessary to economy, the required strength of parts would involve great outlay; maintenance would be costly, and especially so where much of the machinery driven was of a reciprocating character and intermittently employed. As at present designed, moreover, the most economical hydraulic motors cannot be employed to work at high speeds; while the enormous strain to which such machinery is subject sets a limit to the size as well as the speed which may be practically attempted.

Pneumatic transmission really seems to offer greater advantages than either of the preceding. These were fully seen and perhaps overrated at a time when experience in air compressing was very limited, and before the science of thermodynamics had acquired the shape in which it is now applicable to the uses of the engineer. It was not known that the loss of work in the form of heat during the process of compression and storage is sufficiently great to place a limit upon the application of compressed air as a transmitter, and that this loss would generally preclude its employment except in situations where the necessity for power is sufficiently urgent to make the question of cost of compressing power of minor importance. The latter objection, however, loses force when the compressing power can be obtained at little more than that of the necessary machinery for utilizing natural sources of power otherwise lost or wasted. A prominent illustration of this was the employment of air in the Mont Cenis tunnel, compressed by water power otherwise unused. In such a case as this, the great difference between the quantity of power expended in compressing the air, and that which can be realized by the best machinery worked by it, is of secondary importance, as the cost of the original power is nominal. In an article "On Water in Aid of Steam Power," in our impression for the 15th of October, 1875, we pointed out some of the places in our own islands whereat immense power is found concentrated at single spots, but which is wholly lost to man because it happens to exist at places where manufactures or industries cannot be advantageously established, though some of this power could be had for a mere nominal cost per horse. Much of this power, however, might be utilized if it could be transmitted to the places where it is required, and this transference, therefore, seems to be a question of sufficient importance to merit the careful consideration of engineers. In the article already referred to we showed that in Ireland alone there is running to the sea a quantity of water, the mechanically utilizable part of which would give 20,000 horse power at the lowest estimate. This enormous quantity of available energy is resident in five places, and for want of means of transmission to sites of employment, is wholly lost. There are many spots in Scotland, and a few in England, and very many abroad, where other large quantities of water pass on to the sea without being on their way made to act as the servants of man. Machines for compressing air, and that for reproducing the power which may be realized from that air transferred to a distance, have during the past few years been so much improved, that there seems sufficient reason to believe that such sources of power might be made to do duty in a variety of ways. The maximum distance to which air might be usefully transmitted would depend upon data not yet ascertained; but from what is already known, it seems that the loss of pressure due to friction in pipes amounts to from 5 to 6 per cent. per mile for a distance of from four to seven miles. The number of centers of population which could be supplied with power from one place would therefore not be great.

In many cases, however, a considerable number of villages and perhaps several towns might be supplied with power sufficient to accomplish the work of water supply, sewage pumping, etc., and in some cases to perform work in factories. Particularly, however, we would draw attention to the large quantity of force which might be utilized for agricultural purposes within a comparatively short radius of any center of water power. The whole of the work of cultivation and food preparation, including thrashing and some harvesting, might be thus effected. The method of transmission remains to be selected. We have dwelt most upon the use of compressed air, which has now been sufficiently tried to make it pretty well certain that of every 100 horse power at a waterfall, from 40 to 45 might be realized at a farm at, say, from one to three miles distant. In some cases, however, difficulties would be met with in laying pipes for the transference of the air compressed at the waterfall. The power realizable by means of the fixed air motor at the farm might also in some cases be with difficulty transferred to the implements in distant fields. In view of those cases, it may be suggested that the apparent success in the fields at Sermaize of the electro dynamic apparatus, which we illustrated in our impression for the 13th of June, gives some indication that electricity may come to the aid of the farmer in transmitting power. It seems that at a distance of about a mile, the work realizable by the electro-dynamic machinery is from about 40 to 50 per cent. of that done upon the dynamo-electric machine, which in our case would be situated at the waterfall. At present the practical experience with this apparatus is perhaps not sufficient to justify any very definite statements as to its ultimate value, but enough is certainly known to make it fully evident that vast amounts of power, now wholly lost, might be made to do farm work. The electrical apparatus offers the great advantage of facility of transference, and the cable from the falls once laid or carried upon posts might remain in good order and without need of attention for years, and in this it offers advantages which might not always belong to transmission by compressed air in pipes. There are cases where the electrical transmission of power to fields might be found to be economical even when the electricity had to be generated by steam power. A really excellent fixed engine might be placed in the center of a farming district, and in a position to secure a good supply of water and the delivery of fuel at

a minimum cost. This engine might work dynamo-electric machines and supply electricity within certain distances at a cost which would not greatly exceed the expense of steam power by ordinary farm engines, when the expenses of repairs and of carting water and fuel to these are taken into consideration. Power so transmitted might without doubt be made to replace horses for plowing with economy. The facility with which power may be transmitted by electric cables, and the ease with which it may be controlled, suggests that it should have a wide application in the ways we have suggested, and particularly it should be made the means of carrying the power of unutilized waterfalls to the fields and barns of the farmer.—*The Engineer.*

BLASTING BY MEANS OF COMPRESSED AIR.*

By Mr. W. E. GARFORTH.

IN endeavoring to dispense with the use of gunpowder and other explosives in mines, some chemical compounds and a great number of mechanical appliances have been tried with more or less success. In many cases letters patent have been taken out for breaking down coal by hydraulic apparatus, and by wedges of peculiar construction. The first patent taken out to use highly compressed air was by Mr. Macnab, of South Wales, and this was followed, some time afterwards, by Mr. Marsh's patent. These gentlemen, therefore, may be said to be the originators of the compressed air cartridge principle. As my intention is to lay before you the result of experiments with compressed air at a pressure of 8,000 lbs. and upwards per square inch, I will endeavor to explain the principle as briefly as possible.

About two years ago a machine was invented which can now be worked by two men. It is portable, and of dimensions suitable for even small mines, and by means of it air has been compressed to 946 atmospheres, or 14,200 lbs. per square inch. After the air is compressed it is conveyed through wrought-iron pipes to a cast-iron cartridge (say) 11¼ in. long, which is placed in a hole drilled in the coal, from 30 to 40 inches deep, and when the breaking strain of the cartridge (which is ascertained beforehand) is reached, it bursts and breaks down the coal. No doubt there are many members present who have air compressing engines working at 40 lbs. or 60 lbs. pressure per square inch, for the purpose of driving underground hauling and pumping engines, who will admit that in trying to compress air to 70 lbs. or 80 lbs. pressure per square inch they have experienced many disappointments, owing to the air valves proving defective, loss of air through "churning," and the exhaust passages getting blocked with ice and snow. Considering these difficulties it will readily be understood the trouble that has been experienced in obtaining a pressure of 14,200 lbs. per square inch.

Although I should like to enter into a full account of the construction of the machine, and of the manner in which this enormous pressure is obtained, also as to the theory of the vaporized state of highly compressed air, yet, as this detailed information would occupy too much time, and a view and examination of the machine would be a simpler method of enabling you to understand its construction, I propose in this paper to simply inform you that the rams or plungers of the machine are comparatively a loose fit, the valves are as simple as the commonest pump clack or bucket (and can be changed in two or three minutes time), and all the parts are extremely simple in construction and not liable to derangement. With regard to the form and strength of the pipes and cartridge several obstacles had to be overcome. In the first instance the cartridges were made by Mr. Marsh, of tin, afterwards of cast-iron; the latter were, however, very imperfect in construction, varying in thickness as much as 3-16ths of an inch, and altogether unreliable. This was one of the reasons—though not the principal one—why the experiments Mr. Marsh conducted at Wigan were so unsuccessful. The cartridges are now made by means of a machine, and are so perfect and regular that by adding 1·32 of an inch to the internal diameter, the bursting pressure can be ascertained to ·25 per cent. between one cartridge and another, and this uniformity has many times been proved by actual experiment.

At my suggestion, and by the kind permission of Mr. Rothwell, the machine was, some months ago, taken down one of the collieries at Denton. The first attempt to break down coal was a failure, owing to the cartridge not being a tight fit in the hole, which had been made by a common drill in the ordinary way, and instead of the bursting cartridge producing an immediate and sudden effect on the coal, it was gradual and simply resulted in the air around the cartridge being compressed.

I have had the experiments which were made by Mr. Marsh at Wigan fully described to me, and considering the important alterations which have since been made, among others, driving the machine (which now only requires one half the power it formerly did), the improvements in the cartridges, but especially as regards the hole being properly drilled, I can easily understand that without these vital improvements the experiments at Wigan could not be less than a failure. After the first experiment at Denton I suggested to Mr. Reuss that the hole in the coal should be drilled by a small machine, and made so true that the cartridge would fit it tightly, so that if possible not a unit of force should be lost. Without describing the numerous visits which Mr. E. Reuss and I have made down the pit to perfect this drilling machine, nor the principle that coal can be chipped much easier than ground, I may state that by constant thought on Mr. Reuss' part the drilling machine is now so perfect that it can be easily fixed ready for drilling without props and at any angle, also that it has often bored a hole in the coal 6 in. in depth in two minutes' time.

After several months' experimenting with the drilling machine, another trial was made to burst down the coal, and was so far successful as to warrant the construction of an entirely new machine, capable of compressing air to 1,323 atmospheres, or 20,000 lbs. pressure on the square inch—one that would remedy the many defects of Mr. Marsh's old machine, which had been found, during the experiments, weak in most of the working parts—and, in having only four rams, the turning was irregular, and the supply of air intermittent. This new machine has been made by Messrs. Garforth, of Dukinfield, and has already compressed air to 14,200 lbs. per square inch, or 946 atmospheres, and is capable, I fully believe, of giving 20,000 lbs. pressure per square inch. It is neither so high nor so long as the first machine, being only 4 ft. 5 in. long, 3 ft. 4 in. high, and 20 in. wide, and weighing 8 cwt. 2 qrs. 7 lbs., including draw bar, handles, and all accessories. It can be adapted to any gauge on an ordinary colliery tramway.

By the kind permission of Messrs. Marland, of Hollinwood, and Mr. Smith, their manager, a trial was made at Bower Colliery, in the presence of some members of this society, under the following conditions: The coal is known as the Bower Mine; it is 5 ft. thick, and of a very hard nature; it was undercut to a depth of 4 ft. 6 in., and by the drilling machine a perfectly true hole was cut 39½ in. in depth, and 7 ft. from the cut end of the coal. The cast iron cartridge, 11¾ in. long, 3 1-16 in. diameter, 9-16 in. thick, was then put in this hole, and stemmed tight, the pipes and machine were next attached, and at 9,550 pounds, or 636 atmospheres pressure per square inch, the coal was broken down. The quantity was estimated at between 5 and 6 tons.

Having now described to you some of the difficulties which have been experienced in perfecting the cartridge, the air compressing and drilling machines, and also the effect of 9,550 lbs. pressure on the coal, I will endeavor to place before you my ideas of how this power can be utilized. I must first state that among other points the following have been proved:

(*a.*)—That 14,200 lbs. has been (and I venture to think 20,000 lbs. pressure per square inch may be) obtained.

(*b.*)—That a pressure of 9,550 lbs. has been proved to be sufficient to break down the coal in a hard mine like that of Bower Colliery.

(*c.*)—When the air at these great pressures is obtained, it can be kept for hours both in the machine pipes and cartridges.

In making the following suggestions as to how this power may be utilized, I think a machine to meet the requirements of deep mining should be one that would not require much manual labor, owing to the high temperature consequent on deep and extensive workings.

What I propose is to use a vessel or small receiver made so very strong that the bursting point will be six or seven times the required pressure—one proved beyond doubt to be perfectly safe in transit, also of such a capacity as will allow the highly compressed air to expand into the pipes and cartridges without reducing the pressure below the known bursting point of such cartridge. The air compressing machine necessary to fill this receiver with highly compressed air may be fixed on the surface, or, if preferred, at the bottom of the shaft, and worked by steam or compressed air at 40 lb. pressure per square inch in the ordinary way. These portable receivers should then be charged with air of the required pressure, sent into the various working places, attached by means of a speaking valve and pipes to the cartridge placed in the coal, and then by simply opening such valve the air in the receiver would rush into and explode the cartridge, at the same time breaking down the coal without much manual labor. Of course it will be understood that the receiver can either be placed at a safe distance, or to obviate the use of pipes, it can be placed near to the face of the coal, and the valve opened by other means.

If the expansion of the air necessitated a larger receiver, a small hydraulic pump could be connected to it, and by forcing water through a valve opening upwards, the water would then occupy the space of the air, and by this means any pressure which had been lost through expansion could be recovered, and if necessary increased. As water is, comparatively speaking, incompressible, the time taken to effect this operation would not be long, nor the labor very great, and the same water could be used over and over again. This arrangement is the one which I think will be eventually adopted.

In the same way in which machines are altered and the original idea improved upon, I feel convinced that in a short time this great force of 10,000, 15,000, or 20,000 lbs. pressure per square inch will be so utilized that we shall be able to put into the hands of the miner a power which, if gunpowder and other explosives are prohibited, will enable him to get coal with the same facilities as now, but above all without loss of life from blown out shots and explosions, and without the production of deleterious gases, which so seriously affect the ventilation of any mine.

It may appear strange to old miners to propose to place small machines in the hands of each workman, but certainly not more so than it did to engineers when men chipped or worked by hand what is now done by planing, riveting, and other machines. When we consider the restrictions at present placed upon the use of gunpowder and other explosives in mines, and that every day the coal to be gotten lies at a greater depth, and the difficulties in getting increase more than *pro rata* with such depth, I think there can be little doubt that in a few years Government will either entirely prohibit or place more stringent restrictions on the use of gunpowder. I now propose to compare the system of breaking down coal by means of gunpowder with that of compressed air at 8,000 lbs. pressure or upwards per square inch. The undermining of the coal will in both cases be about the same, also the time taken to drill the hole, provided the machine drill is used. If the arrangement of receiver as proposed in the foregoing remarks be carried out, then the time taken to fire the gunpowder or burst the cartridge by compressed air will likewise be about the same. In stemming the hole there will be a gain in favor of gunpowder of about ten minutes, but at a much greater risk.

If, instead of the portable receiver the machine had to compress the air to the required pressure, then there is a gain of 25 to 35 minutes in favor of gunpowder; but, as we are all aware, after an explosion of gunpowder, the working place if not well ventilated is so filled with powder smoke for a quarter, half, and even three-quarters of an hour, that the advantage gained in the time is quite counterbalanced. Compressed air, however, possesses advantages over gunpowder, as regards its safety, which cannot be too highly estimated.

I think every one connected with mining will admit that the time has now arrived for some power to be found to supply the place of gunpowder, if it be prohibited, to enable us to get coal as economically in the future as now. Should gunpowder and other explosives be prohibited, what is the next best means for supplying their place? I think, for the reasons I have stated, that compressed air will stand foremost as a substitute, more especially on account of its safety, and although monetary considerations may to a certain extent weigh with some people, yet no one can for a moment deny, after seeing the lavish expenditure made by colliery proprietors for the safety of their men, that safety is the main consideration both of mine owners and their managers.

* Transactions of the Manchester Geological Society.

SEVEN persons have been poisoned in Amsterdam, Holland, by the use of enameled-iron cooking vessels of German and Belgian manufacture. Prof. P. F. Van Hamel-Roos recently tested some of these utensils. On analysis, the solution thus obtained yielded a considerable quantity of oxide of zinc. The combinations of zinc are considered to be very injurious to health.

THE AMERICAN RIVER PADDLE WHEEL STEAMBOAT "MARY POWELL."

By CHIEF ENGINEER ISHERWOOD, U. S. Navy.

THE Mary Powell is a typical example of the American paddle wheel steamboat employed on the rivers of the eastern portion of the United States. The hull is of wood, coppered, and is exceedingly light and shallow, depending for strength on an immense timber truss, or "hog frame," erected on each side, and on a very deep keelson supporting, along the center of the vessel, poles rising many feet above the roof of the saloon, from the tops of which sloping iron rods suspend the guards and ends of the hull. Of course, such a structure is suitable for smooth water only, and the elegant saloons erected upon it, of light joiner-work, afford spacious and convenient accommodations for the crowds of passengers carried.

The Mary Powell plies between New York City and Rondout, on the Hudson River, a distance of about 88 statute miles, making the round trip once a day during the summer season of each year, extending from about the middle of May to the middle of October. She carries passengers only, and her trips are made with great regularity, the times of starting and stopping varying but a few minutes from her schedule time. Her draught of water varies very slightly also, and her speed throughout the entire run may be taken, without sensible error, as absolutely uniform. The air resistance of the hull, must, at its high velocity, be considerable, as the top of the saloon is about 30 feet above the water, while the immersion of the hull, exclusive of the keel, is only 6 feet.

There is but one engine—placed in the center of the vessel and bolted to its keelsons—and it is as typical as the hull, being a first class specimen of the overhead beam, or walking beam kind, used exclusively on such steamboats, the beam being supported upon a lofty triangular gallows frame of wood, very stiff and very light. The boilers, also, are peculiar to this style of steamboat. They are two in number, and placed outside of the hull upon the projecting guards behind the wheel houses. This is the only place available for them, and as no more boiler space can be obtained than there is room for on these guards, their rate of combustion has to be forced enormously by powerful fan blowers to furnish sufficient steam for the large power required. Independently, too, of the limited space that can be devoted to the boilers, no greater weight of them can be allowed, even if more space was available. Anthracite of small nut size is burned, giving about one-sixth refuse. The vessel is coaled at Rondout, and carries just enough for one round trip. The paddle wheels are of the usual radial kind. For river steamers carrying large numbers of passengers, no system, as a whole, has ever been devised equal to the paddle wheel steamboats of the Mary Powell type.

The entire machinery, with its appurtenances, including the water in the boilers, weighs about 210 tons; the coal embarked weighs about 30 tons; total in the engineer department, 240 tons, or 27·24 per centum of the vessel's displacement.

As there is no account to be found of the performance of such a vessel, my friend, the accomplished engineer, Mr. Theron Skeel, having occasion to make many trips in the Mary Powell during the summer of 1877, kept for me an accurate record of her running time between the cities of New York and Newburg, 59 statute miles apart, together with the boiler pressure, vacuum, temperature of the feeding water, revolutions of the motive and blowing engines by counter, consumption of coal, etc., the coal being the amount purchased by the owner of the boat. He also took on each trip a large number of indicator diagrams from both ends of the cylinder, and made the other observations to be found in this article. The means from all these diagrams are given in the table of performance.

During the round trip no water was blown from the boilers, and they remained entirely free of scale. There was no means of ascertaining the temperature of the gases of combustion in the chimney, but a piece of zinc suspended therein at the level of the top of the steam drum melted promptly, showing the temperature to be above 750 degrees Fahrenheit. The temperature of the steam in the boiler, considered as saturated steam, would be 272 degrees Fahrenheit, or more than 478 degrees Fahrenheit less than that of the gases of combustion passing through the steam drum, which difference, taken in connection with the large extent of surface in the drum and upper part of the uptake, must have caused a considerable steam superheating. There was no means, however, of ascertaining this fact quantitatively, but it is believed that the superheating was sufficient to prevent any steam condensation in the cylinder other than that due to the development of the total horse power.

In the table of performance hereinafter given will be found grouped all the quantities observed and calculated. The power developed is that of the motive engine alone, exclusive of the power exerted by the blowing engines in driving the fans. Of the latter power no approximation can be made, as these engines used the steam greatly throttled but exhausted into the condenser. The weight of steam used, calculated from the indicator diagrams, is also exclusive of the weight consumed by the blowing engines; hence, if it be assumed that there was no condensation in the cylinder of the motive engine other than that due to the development of the total horse power, then the cost of the horse power in weight of steam consumed per hour can be ascertained. As the motive engine developed 1,744·884 total horse power, and as the indicator accounted for 38,258·264 pounds of steam consumed per hour in its cylinder, there follows that the total horse power was obtained for 21·93 pounds of steam consumed per hour.

The economic vaporization by the boilers can be ascertained, without error of practical importance, by assuming the weight of steam consumed by the blowing engine to be five per centum of the weight consumed by the motive engine. Adding this weight to the 38,258·264 pounds of steam consumed by the motive engine per hour, there results 40,171·177 pounds of steam evaporated per hour, from water at the temperature of 120 degrees Fahrenheit, and under the boiler pressure, by 6,050 pounds of anthracite, or 6·64 pounds of water vaporized per pound of coal. This, of course, supposes no condensation in the motive cylinder, which was probably the fact, an inference warranted by the superheating of the steam, by the above cost of the total horse power in pounds of steam consumed per hour, and by the boilers' economic vaporization of 6·64 pounds of water per pound of coal consumed at the great rate of 39·286 pounds per square foot of grate surface per hour.

In computing the quantity of heat transformed into the total horse power developed by the expanded steam, the mechanical equivalent of the heat required to raise the temperature of one pound of water from 33 to 33 degrees Fahrenheit is taken at 789¼ pounds, instead of Joule's equiva-

lent of 772 pounds. The latter has long been known to be too small, and the former is the result of the experimental researches of Tresca and Laboulaye, indorsed by Regnault, Piobert, Combes, Bertrand, and Morin. It should be universally adopted.

HULL.

Length on the load water line from the forward edge of the rabbet of the stem to the after edge of the stern post	290 ft.
Extreme breadth on the load water line	34 ft.
Depth of hold from top of floor timbers to under side of deck plank	9½ ft.
Depth from load water line to lower edge of rabbet of keel	6 ft.
Depth of keel below the lower edge of its rabbet	6 in.
Area of the greatest immersed transverse section to load water line	198·5 sq ft.
Displacement to load water line	881 tons.
Ratio of the length to the breadth	8·529
Ratio of the greatest immersed transverse section to its circumscribing parallelogram	0·973
Ratio of the displacement to its circumscribing parallelopipedon	0·520

ENGINE.

There is one overhead beam engine with a wooden gallows frame. The cylinder is vertical and has four balanced pop pet valves, two for admitting and two for exhausting the steam. The steam valves function also as expansion valves by means of the mechanism known as Stevens' cut off. The condensation of the steam is effected in a jet condenser. The air pump is vertical and single acting. The cylinder is not steam jacketed; its ends, its valve chests, and its side pipes have no protecting covering, but its cylindrical portion and all the steam piping connecting it with the boilers were well covered with asbestos felting.

During the performance hereinafter given, the steam valves closed when 0·486 of the piston was completed. There was but little exhaust lead, and the exhaust valves closed and cushioned the steam when the piston was at 0·232 of its stroke from the end.

Number of cylinders	1
Diameter of cylinder	72 in.
Diameter of the piston rod	6⅛ in.
Net area of the piston, exclusive of the piston rod	4,053·62 sq. in.
Stroke of the piston	12 ft.
Space displacement of the piston per stroke	337·802 cub. ft.
Clearance of the piston	1⅝ in.
Capacity of steam passage or nozzle at one end of cylinder	8·488 cub. ft.
Aggregate space in clearance and steam passage at one end of the cylinder	12·300 cub. ft.
Least diameter of the seat of the upper disk of the steam valve	15⅜ in.
Least diameter of the seat of the lower disk of the steam valve	14¾ in.
Least diameter of the seat of the upper disk of the exhaust valve	14¾ in.
Least diameter of the seat of the lower disk of the exhaust valve	15⅜ in.
Area of steam port, exclusive of valve stems	352 sq. in.
Diameter of air pump (single acting)	40 in.
Stroke of air pump piston	62 in.

BLOWING ENGINES.

There are two blowing engines—one for each boiler—employed in driving fan blowers to produce an artificial draught. Each blowing engine consists of one cylinder 12 inches in diameter, with 12 inches stroke of piston, geared by a belt to a Dimpfel blower, 5 feet in diameter and 32 inches wide, which makes five revolutions to each double stroke of the steam piston. The steam is cut off by lap on the steam valve at three-fourths of the stroke of the piston from the commencement.

The delivering nozzle of each fan blower is connected by a rectangular conduit of sheet iron with the closed front of the two ash pits of its boiler, and they receive the air-blast beneath the grate bars.

BOILERS.

There are two boilers, one placed on each guard of the vessel immediately behind the wheel house. They have lower flues in direct continuation of the furnaces, with tubes returned above the flues and furnaces. The two boilers have no connection of any kind; they have separate chimneys, are fed separately with both water and air blast, and deliver their steam through separate pipes into one large steam pipe. The external surfaces of the boilers are well covered with asbestos felting. The following is a description of each boiler:

The front portion of the shell is rectangular in plan, with flat sides and a semi-cylindrical top. The back portion is cylindrical, with its top a horizontal continuation of the top of the semi-cylinder of the front portion. The front portion is 10 feet 9 inches high, exclusive of water pan beneath the grates, 8 feet 11½ inches long, and 11 feet wide. The back portion is 10 feet in diameter and 16 feet 1 inch long, with its bottom 9 inches above the bottom of the front portion.

The furnaces are two in number, each 4 feet 9¾ inches wide by 8 feet long. The crown is an arc of 7 feet 3 inches radius, joined to the vertical sides by quadrantal curves of 8 inches radius. The flat water space between the furnaces is 6½ inches wide, and between the furnaces and shell 5 inches wide, including thicknesses of metal.

The opening for the furnace door is semi-circular on top, 22 inches wide and 22 inches high. The height from the top of the grate bars to the top of the furnace is 3 feet. The bridge wall is 7 inches wide, including thicknesses of metal.

Immediately behind the bridge wall is a combustion chamber, separate for each furnace. Its extreme height is 3 feet 2 inches and its length is 3 feet. In cross section its outline follows the side and top of the furnace, the curve of the lower flue and of the cylindrical part of the shell, from which it is separated by a water space 3½ inches wide, including thicknesses of metal.

From the combustion chamber to the back smoke connection there proceed, for each furnace, three lower horizontal cylindrical flues of 10 inches inner diameter, one lower horizontal flue of 14 inches inner diameter, and one of 9 inches inner diameter. All these flues are 9 feet 1 inch in extreme length. The least water space between them is 4⅛ inches, including thicknesses of metal.

The back smoke connection is in common for both furnaces. It is flat on the top, and on the sides and bottom is concentric with the cylindrical part of the shell, from which it is separated by a water space 3½ inches wide, including thicknesses of metal. The extreme height is 6 feet 4 inches, extreme breadth 9 feet 5 inches, extreme length 3 feet 7½ inches, all in the clear. The flat water space between the end of the connection and the shell is 4½ inches wide, including thicknesses of metal. Access is had to the connection through a manhole of 18 inches diameter in the back end of the boiler.

From the back smoke connection to the uptake there are returned over the lower flues and the furnaces 80 horizontal fire tubes of 4⅛ inches outside diameter and 4·30 inches inside diameter; length, 16 feet 6 inches. The tubes are distributed in 5 rows vertically and 16 rows horizontally. The least distance from center to center of tubes, both vertically and horizontally, is 6·357 inches. The space in the clear, between the bottom of the lower row of tubes and the furnace crown, is 7 inches. The height from the top of the upper row of tubes to the bottom of the lower row is 2 feet 4 inches. The heating surface of the tubes is calculated for their inside circumference, which is also the case for the flues.

The uptake is in common for all the tubes. The lower portion is rectangular, 8 feet 8 inches in extreme breadth, 55 inches in extreme width to the front of the shell, and 31 inches in height. It is fitted with the usual uptake doors, giving access to the tubes for sweeping. The upper portion is irregularly shaped, drawing in to a circle of 50 inches diameter at the top of the shell.

From the top of the uptake rises the chimney, 50 inches in inner diameter. The lower portion of the chimney, for a height of 12 feet above the top of the shell, is surrounded concentrically by a steam drum of 90 inches diameter with a flat top. The portion of the chimney so surrounded, together with the upper portion of the uptake, is steam superheating surface.

All the flat surfaces of the boiler are braced every 7 inches.

The following are the principal dimensions and proportions:

Number of boilers	2
Extreme length of boiler, exclusive of projecting steam drum	25 ft. ½ in.
Extreme height of boilers, exclusive of steam drum	10 ft. 9 in.
Extreme breadth of boiler	11 ft.
Height of steam drum above the boiler shell	12 ft.
Projection of steam drum forward of the boiler shell	1 ft. 3½ in.
Total number of furnaces	4
Width of furnace	4 ft. 9¾ in.
Length of furnace	8 ft.
Aggregate area of grate surface	154 sq. ft.
Number of lower flues	20
Length of lower flues	9 ft. 1 in.
Inner diameter of lower flues, 4 of 9 in., 4 of 10 in., and 12 of 16 in.	
Number of tubes (iron)	160
Length of tubes	16 ft. 6 in.
Outside diameter of tubes	4⅛ in.
Inside diameter of tubes	4·30 in.
Least space between tubes, in the clear	1·857 in.
Aggregate area of heating surface in the furnaces	416·00 sq. ft.
Aggregate area of heating surface in the combustion chambers	262·00 sq. ft.
Aggregate area of heating surface in the lower flues	338·00 sq. ft.
Aggregate area of heating surface in the back smoke connections	62·70 sq. ft.
Aggregate area of heating surface in the tubes	2,971·94 sq. ft.
Aggregate area of heating surface in the uptakes, to 9 inches above tubes	675·36 sq. ft.
Total water heating surface	4,726·00 sq. ft.
Aggregate area of steam superheating surface	418·00 sq. ft.
Distance traversed by the gases of combustion from the center of the furnace to their delivery into the uptake	40 ft.
Diameter of chimneys (two in number)	4 ft. 2 in.
Height of chimneys above level of grates	52 ft.
Aggregate cross area over bridge walls, for draught	22·500 sq. ft.
Aggregate cross area through lower tubes, for draught	22·798 sq. ft.
Aggregate cross area through the tubes, for draught	16·130 sq. ft.
Aggregate cross area of the chimneys	27·373 sq. ft.

PROPORTIONS

Square feet of water heating surface per square foot of grate surface	30·558
Square feet of steam superheating surface per square foot of grate surface	2·714
Square feet of grate surface per square foot of area over bridge walls	6·844
Square feet of grate surface per square foot of area through lower flues	6·755
Square feet of grate surface per square foot of area through tubes	9·544
Square feet of grate surface per square foot of area through chimneys	5·647

PADDLE WHEELS.

The paddle wheels are of the ordinary radial kind

Diameter from outside to outside of paddles	31 ft.
Number of paddles in each wheel	26
Length of each paddle	10½ ft.
Breadth of each paddle	1¾ ft.
Deepest immersion of outer edge of paddles	3½ ft.

PERFORMANCE.

The following is the average performance of the Mary Powell, between the cities of New York and Newburg, on the Hudson River, during the summer of 1877. The running was very regular, the deviations at any time from the mean being very slight.

VESSEL.

Vessel's mean draught of water, in feet	6½
Vessel's greatest immersed transverse section, in square feet	198·5
Vessel's displacement, in tons	881
Deepest immersion of the outer edge of the paddles, in feet	3·50
Diameter of the paddle wheel between centers of pressure of the paddles, in feet	29·50

ENGINE.

Steam pressure in boilers, in pounds per square inch above the atmosphere	28·5
Proportion of the throttle valve open	0·75
Fraction of the stroke of piston completed when the steam was cut off	0·486
Fraction of the stroke of the piston to be completed when the steam was cushioned	0·232
Number of times the steam was expanded	1·984
Vapor pressure in the condenser, in pounds per square inch above zero	2·4
Number of double strokes made by the piston per minute	21·8
Temperature of the injection water in degrees Fahrenheit	68
Temperature of the feed water (hot well) in degrees Fahrenheit	120
Number of double strokes made per minute by the pistons of the blowing engines	75
Number of revolutions made per minute by the fan blowers	375
Air pressure in the fan blower conduit, in inches of water, above the atmosphere	1¼

STEAM PRESSURE IN CYLINDER PER INDICATOR.

Steam pressure in cylinder, in pounds per square inch above zero, at beginning of stroke of piston	41·42
Steam pressure in cylinder, in pounds per square inch above zero, at point of cutting off the steam	31·34
Steam pressure in cylinder, in pounds per square inch above zero, at end of stroke of piston	16·42
Mean back pressure against the piston, exclusive of the cushioning, in pounds per square inch above zero	3·55
Mean back pressure against the piston, inclusive of the cushioning, in pounds per square inch above zero	5·31
Mean indicated pressure on the piston in pounds per square inch	24·42
Mean net pressure on the piston in pounds per square inch	22·92
Mean total pressure on the piston, exclusive of the cushioning, in pounds per square inch	27·15

HORSE POWER.

Indicated horse power developed by the engines	1569·432
Net horse power developed by the engines	1473·029
Total horse power developed by the engines, exclusive of the cushioning	1744·884
Horse power expended on the cushioning alone, above zero	165 812
Horse power expended on the cushioning alone above the back pressure of 3·55 pounds per square inch against the piston	113·112

RATE OF COMBUSTION.

Pounds of anthracite consumed per hour	6050·000
Pounds of anthracite consumed per hour per square foot of grate surface	39·286
Pounds of anthracite consumed per hour per square foot of water heating surface	1·280

ECONOMIC RESULTS.

Pounds of anthracite consumed per hour per indicated horse power	3.855
Pounds of anthracite consumed per hour per net horse power	4·107
Pounds of anthracite consumed per hour per total horse power	3·467

SPEED.

Speed of the vessel per hour in statute miles of 5,280 feet	19·200
Speed of the vessel per hour in geographical miles of 6,086 feet	16·657
Slip of the center of pressure of the paddle in per centum of its speed	16·37

WEIGHT OF STEAM CONSUMED.

Fahrenheit units of heat transformed per hour into the total horses power developed by the expanded steam, calculated for the mechanical equivalent of one Fahrenheit unit, 7891¼ pounds raised one foot high per minute	1,823,195·554
Pounds of steam of the boiler pressure required to be evaporated from water at the temperature of 120 degrees Fahrenheit to contain the above number of Fahrenheit units of heat	1895·741
Pounds of steam supplied per hour by the boiler to the cylinder, calculated from the pressure at the end of the stroke of the piston and from the back pressure cushioned	36,362·523
Sum of the two immediately preceding quantities, or weight of steam in pounds consumed per hour, according to the indicator	38,258·264
Pounds of steam cushioned per hour	2365·428

—*Journal Franklin Institute.*

MULTIPLE PRESSURE SUGAR MILL.

WITH INJECTIONS OF WATER, STEAM, AND LIQUOR BETWEEN EACH PRESSURE.

The special feature of this sugar mill—the first which has been made with such a large number of rollers—is that the canes are not only submitted to successive and increasing pressures, but that, whilst passing under the rollers, before each of the last three pressures, they are injected at the will of the attendant of the apparatus, with either steam, liquor, or water. The liquor used for this purpose is derived from the two last pressures, and is directed on to the preceding ones in the same order as their degree of density according to the saccharimeter.

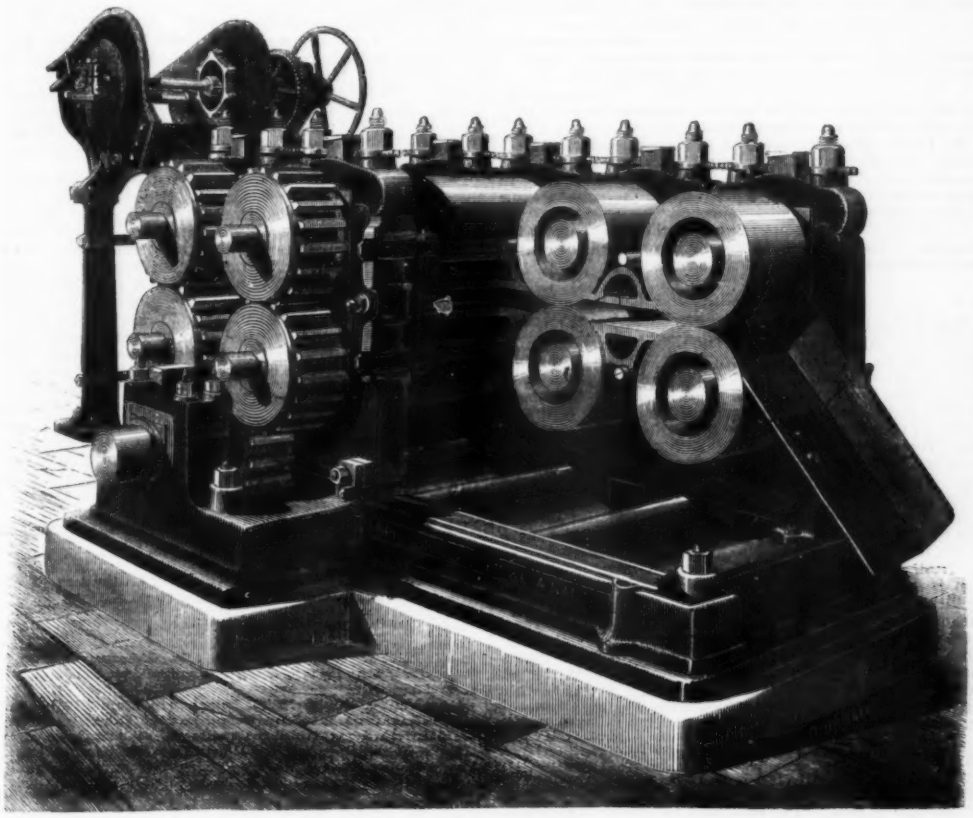
It is this system which the inventors have called the "Multiple Pressure Sugar Mill," for which they have recently taken out a patent.

It is well known that, according to different analyses, sugar cane, when ripe, and when freshly cut, has the following composition:—

Water	72.00	100
Sugar	18.00	
Cellulose, and ligneous matter	9.50	
Insoluble salts	.50	

Up to the present time, with the different forms of apparatus employed for extracting the juice from sugar cane, and the use of the most improved machinery, such as *triple effets* and vacuum-pans, no more than from 8½ to 9 kilogrammes of sugar have been obtained per 100 kilogrammes of crushed cane; and this result has only been obtained in exceptional years, when the weather has been most favorable for the development and ripening of the canes.

The home sugar industry, however, can reckon a much larger percentage. This is easily explained by the fact of its being able from its situation to employ to the best possible advantage, all the new processes and machinery as they are brought to light, more especially in the large European industrial centers. This superiority in the quantity of sugar obtained, and the number of large works which have been erected during recent late years, have increased in considerable proportions the home sugar production; and, as the consumption has not kept pace with this production, the value of sugar has consequently decreased. As the colonial



MULTIPLE-PRESSURE SUGAR MILL.

planters could not, without danger to their industrial existence, submit to the fall of price, which has taken place, they have endeavored to discover a remedy for this state of things. This remedy has been found by extracting from the cane itself the greatest possible quantity of the 88 or 90 per cent. of juice which it contains.

As the other forms of apparatus, with the exception of the mill, have been successively modified and brought to a comparative degree of perfection, it followed that the roller-mill had also to be improved.

This new apparatus of Messrs. Lahaye & Brissonneau, of Nantes, France, embodies the latest improvement in this direction. This mill, of which the accompanying figure represents a perspective view, is furnished with two pairs of rollers, which are shown in cross section. It has already been working for two years in Guadaloupe, at the Courcelles Sugar Works, belonging to Messrs. Dubos frères.—*Universal Engineer.*

THE ZOOTROPE.

ACTION OF ANIMALS IN MOTION.

WHEN Mr. Edward Muybridge, of San Francisco, assisted by Governor Stanford, made, in the spring of 1878, his first photographs of the horse in motion, it became evident to those who had been previously engaged in studying the subject of the locomotion of animals that they had never before had any such material for their investigations as that which he then presented.

His process, briefly, consists in having a number of photographic cameras on a proper support near the level of the ground, at equal distances, say twenty-seven inches apart. Opposite to the cameras and parallel to the line in which they stand, is a white screen or fence with vertical lines also twenty-seven inches apart, drawn on its surface, one directly opposite to each camera. A wire, with proper electrical connections, leads from each line to the corresponding camera. The animal whose motion is to be photographed, is driven or ridden on a line parallel to the screen in front of the cameras, and as he crosses each wire, the slide of the camera corresponding to that wire is opened, and a photograph of the animal in that position is obtained. In the experiments on a horse at racing speed, for example, the animal covers about twenty-two feet in each stride; ten cameras, therefore, twenty-seven inches apart, would record ten different portions of one stride or step. The photographs thus produced show the successive positions, the transitions from one to the other of which are altogether too rapid to be appreciated by the eye.

A number of investigators have attempted to analyze the action of man and of animals in the various gaits. The Weber brothers, as to man, and Wachter, Raabe, Marey, and Lenoble de Teil, for horses. In fact, nearly all the writers on horsemanship have attempted to analyze the action of the horse, but with indifferent success. Marey's method was the most complete, but when his results are examined by the light of Muybridge's photographs, they are found to be quite unsatisfactory.

Shortly after the appearance of the photographs, Mr. Thomas Eakins, of Philadelphia, Instructor in the Pennsylvania Academy of the Fine Arts, who had long been studying the horse from an artistic point of view, and whose accurate anatomical knowledge fitted him especially for the investigation, took them up for examination. Wachter, in 1862, had published a set of ten drawings illustrating the gallop, the most complicated of the gaits, which he arranged to be used in what was then called the phenakisticope, an instrument which we now know in its improved American form under the name of the zoötrope, and his analysis was so nearly correct that the horse galloped quite satisfactorily when looked at in the apparatus. His ingenious drawings hardly received the notice which they merited, and he seems to have been extremely modest in his own appreciation of their value. The writer, familiar with the work which had been done in this direction, saw immediately that the zoötrope would be a useful instrument in enabling the experimenter to determine whether the photographic analysis was correct, and constructed a large metal zoötrope, with various appliances, for making it a scientific instrument. The idea was of course a very natural one, and it had already occurred to Gov. Stanford and Mr. Muybridge, who had independently done the same thing. The photographs themselves are not exactly adapted for immediate use in the zoötrope. They are too small, and most of them show no interior modeling, but are mere silhouettes, in which the near and off legs cannot be readily distinguished from each other. In some of them, the running horse, for example, the intervals are not equal, owing to a peculiarity of the photographic apparatus, an explanation of which would be too long for the limits of this article, in others the twenty-seven inches is not an aliquot part of the length of a whole stride. To obtain a perfectly satisfactory result, drawings must be made based upon the information given by the photographs.

To do this, Mr. Eakins platted carefully, with due attention to all the conditions of the problem, the successive positions of the photographs, and constructed, most ingeniously, the trajectories, or paths, of a number of points of the animal, such as each foot, the elbow, hock, center of gravity, cantle of the saddle, point of cap of the rider, etc. Having these paths, and marking the beginning of the stride and the exact point at the other end of the diagram, where the beginning of the next stride occurs, the whole stride can be divided into an exactly equal number of parts; twelve has been selected as a convenient number, and the exact position of each point of the body determined for each of the twelve positions.

Although familiarity with the anatomical construction of the animal enables the artist thus to draw each of the twelve positions or attitudes, when the figures thus made are put into the zoötrope a perfect representation of the motion is obtained. By varying the number of the slots, through which the drawings are seen, the animal can be made to move forward or to remain in one place, as he would appear if the spectator were to ride or drive alongside of him at the same rate of speed. The relation of the action to the distance passed over in each stride can be regulated with accuracy. The motion is exceedingly smooth, and such things as the waving of the tail or the mane are shown in the most natural manner. It is of course possible to reduce to the slowest speed, for the purpose of study, the action of the horse at his top speed, which is so rapid that the eye fails to catch the details of it in nature.

An addition to the zoötrope is now being made by which, at the moment at which each foot appears to the eye to strike the ground, a sharp tap of a small hammer will be made by the instrument, and the cadence of the step will be made manifest to the ear, and will aid materially in the study of the motion.

It is obvious that while the photographs and the drawings made from them are the analysis of the motion, the combination of them in the zoötrope is the synthesis, and is a complete test of the accuracy of the analysis. Mr. Muybridge intends to continue his experiments, and will accumulate a mass of information which will be of the utmost value. At the suggestion of Mr. Marey, whose investigations in the same line, with entirely different means, have been very important, he will probably make corresponding photographs of the flight of birds.

The value of these investigations to the artist is very great. It is certain that nearly all the attempts to represent the gaits of either animals or men, in painting, are extremely unsatisfactory, and it is only by thoroughly understanding the mechanism of the motion that the artist will be able to portray it in any satisfactory manner. A glance at the Muybridge photographs of the running horse shows that the position of the legs, which is usually accepted as representing a full run, as drawn by the best painters of horse subjects, is not only incomplete, but absolutely incorrect, and must be universally so recognized as soon as correct information is obtained by those who criticise such works. There are many interesting speculations as to how this new information may be utilized by the painter, for which we have no space at present, but Mr. Muybridge deserves the thanks of all artists for the valuable addition that he has made to the general fund of knowledge.—*Fairman Rogers, in the Art Interchange.*

PHOTOGRAPHY IN COLORS.

CAPT. ABNEY recently submitted to the Royal Society, London, some pictures of the solar spectrum on silver plates, and also on compounds of silver, held in place by collodion. The natural colors of the spectrum had imprinted themselves on the plates, those on the silver being more brilliant than those on the collodion, but the latter could be seen both by transmitted and reflected light. Without entering into details of the process by which he obtained the pictures, he stated in general terms that they were produced by the oxidation of silver compounds during two minutes' exposure with a wide slit. Many months ago, when Becquerel showed examples of natural colors, effected through the agency of light, Capt. Abney said that the probable explanation of the result was the oxidation of the silver compounds employed; and he is now confident that he was then correct, that the colors are not caused by interference. The coloring matter seems to be due to a mixture of two different sizes of molecules of the same chemical composition, one of which absorbs at the blue end and the other at the red end of the spectrum, and the sizes of these molecules are unalterable so long as they are exposed to the same wave lengths as those by which they were produced. He believes it possible and probable that the colors may be preserved unchanged when exposed to ordinary daylight.

SPECIFIC GRAVITY BALANCE.

M. GANNAL has recently devised a simple means of determining the specific gravity of liquids. With his densimeter hydrostatique all calculation is obviated, and the specific gravity is ascertained by simply reading the weight on the balance. The apparatus is made in the form of an olive, so that bubbles of air shall not attach themselves to its sides. The olive of glass or metal has a volume exactly equal to one decimal subdivision of a cubic meter. There are two different methods employed in the practical use of the apparatus. (1) We may suspend it on the platform of the balance, and after having produced an equilibrium, we plunge it into the liquid; the equilibrium is then destroyed by the loss of weight of the olive, and the number of grammes which it is necessary to add to the scale-pan to restore the equilibrium is the exact specific gravity of the liquid. (2) Or the liquid whose specific gravity we desire to ascertain may be put in a glass vessel on one pan of the balance; balance the scale-pans, and then suspend the olive in the liquid by means of a fine thread. The equilibrium is destroyed, and the scale descends on the side on which the olive is suspended, and the weight, which it is necessary to place in the other pan to restore the equilibrium, is equal to the specific gravity of the liquid.

NESSLER has been thus far unable to ascertain when the coloring matters of mallows and bilberries are used to color wine, and he considers it very probable that the natural red coloring of the grape does not differ essentially from these foreign substances.

BY permitting vanadium to act at 200° Centigrade, on a mixture of nitro-benzol and commercial aniline, or on a mixture of pure aniline and nitro-toluol, Schmidt and Baldensperger, of Mulhouse, claim that an excellent magenta can be produced in either case.

ELECTRIC DISCHARGES IN RAREFIED GASES.

MESSRS. DE LA RUE and Müller, in the researches which they have carried on during three and a half years, have contributed facts of the highest value toward the solution of the problem presented by the beautiful phenomenon of stratification produced by electric discharges in vacuum tubes. The results of their labors are given in full in the *Philosophical Transactions.*

The authors state that there is a serious trouble connected with the study of the discharge in rarefied gases, for, after a very short time, the tubes completely and permanently change, so as no longer to present the splendid stratifications witnessed on a first trial. We believe these changes occur much more rapidly with the battery in consequence of the greater amount of current than with the induction coil; but the fact appears to have been well known to Dr. Geissler, of Bonn, who, on the occasion of a visit to our laboratory, brought with him some tubes through which no current had previously passed (virgin tubes, as he called them), which presented most beautiful phenomena lost for ever after too brief a period.

A cyanogen tube, for example, when first connected with the battery, presented strata which completely filled the tube without leaving a dark space near the negative, some threading themselves on it, but after a few seconds the strata widened out as on the right hand figure, then other changes occurred, and the first phases have never been reproduced.

After spending much time in experiments with tubes prepared for us by Dr. Geissler, Messrs. Alvergniat Frères, of Paris, and Mr. Hicks, of Hatton Garden, with the vexation of finding that we could not often enough repeat our experiments, we ultimately came to the conclusion to have others made, but not exhausted, and to perform ourselves the charging and exhaustion. The tubes we usually employ have a glass stop-cock fitted to them at each end; they are 32 inches long, and from 1·75 to 2 inches in diameter; the terminals are of aluminum, and about 29 inches apart,

one being a ring, the other a wire bent at a right angle, so as to point in the direction of the axis of the tube, for we have found that the phenomena vary according as the ring or wire is made positive.

These we exhaust and fill with any gas we may wish to experiment with, and gradually exhaust again, noting the phenomena presented at different pressures, with different potentials, and with different amounts of current. We refill and exhaust the tube again and again, and mostly obtain, under the same conditions, as nearly as possible the same phenomena, of which we are careful to make sketches and, if possible, to obtain photographic records.

The apparatus which we have found it advantageous to adopt for the exhaustion of our tubes comprises three means of exhaustion, which are successively employed as the vacuum becomes more perfect. The first is an Alvergniat high-pressure water *trompe* in connection with the high-pressure water main of the West Middlesex Water Company, the head of water being 106 feet; it produces a vacuum to within half an inch (0·47 in. = 12 millims.) of the height of the barometer. The other end of the vacuum tube communicates by means of a Y-piece to both, an Alvergniat mercurial pump, and a Sprengel pump on the left. After the *trompe* has done its work, the Alvergniat is used for rapid exhaustion, and then shut off, leaving the exhaustion to be completed by the Sprengel; we have thus obtained, by the pumps alone, in tubes 32 inches long and 2 inches in diameter, vacua of only 0·002 millimeter pressure, equal to 2·6 millionths of an atmosphere—a vacuum so perfect that the current of 8,040 cells would not pass. The apparatus is in connection with a McLeod gauge, by means of which pressures to 0·00005 mm. can be determined. Besides this gauge the Sprengel and Alvergniat pumps have their own gauges, which read to a millimeter.

Our observations show clearly that discharge through rarefied gases cannot be at all analogous to conduction through metals; for a wire having a given difference of potential between its ends can permit one—and only one—current to pass; whereas from the measurements obtained, it became evident that with a given difference of potential between the terminals of a given vacuum tube currents of strengths varying from 1 to 135 can flow. We are therefore led to the conclusion that the discharge in a vacuum tube does not differ essentially from that in air and other gases at ordinary atmospheric pressures—that it is, in fact, a disruptive discharge.

In every case where the strata are to the eye or rotating mirror perfectly steady slight deflections of the needle are seen; these generally indicate a resultant direct current (break contact), and in the fewer number of cases an inverse current indicating, in the first case, a sudden decrease and slow increase of current through the tube. These deflections, though very manifest, do not amount to more than about three or four divisions of the galvanometer scale, a deflection which indicates a current of only 0·00000000023 W. At the advent or retreat of a stratum at the positive pole there is frequently produced a deviation of 300 divisions, indicating a current of 0·00000001812 W.; before a stratum leaves the positive terminal or dies out on it, there is usually a tremulous motion of that stratum visible to the eye and indicated by rapid pulsations of the galvanometer.

On the suggestion of Prof. Clerk Maxwell we have recently introduced the telephone into the primary current, and also in the secondary current.

In all cases where the condenser, was discharging itself gradually through the tube, a low rustling sound was distinctly audible to sensitive ears so long as the stratification remained apparently perfectly steady. When the phase of confused stratification which immediately precedes extinction was reached, the sound in the telephone became very loud and rose in pitch, with some tubes becoming quite shrill. These results, therefore, confirm the conclusion already arrived at from other experiments, namely, that the discharge in vacuum tubes is intermittent; but we do not pretend that they make it manifest that stratification is dependent upon intermittence.

In the course of our experiments, using sometimes 11,000 cells, we have arrived at the following facts:

1. The discharge in a vacuum tube does not differ essentially from that in air and other gases at ordinary atmospheric pressures; it cannot be considered as a current in the ordinary acceptation of the term, but must be of the nature of a disruptive discharge, the molecules of the gas acting as carriers of electrification. The gases in all probability receive impulses in two directions at right angles to each other, that from the negative being the more continuous of the two. Metal is frequently carried from the terminals and is deposited on the inside of the tube, so as to leave a permanent record of the spaces between the strata.

2. As the exhaustion proceeds the potential necessary to cause a current to pass diminishes up to a certain point, whence it again increases, and the strata thicken and diminish in number, until a point is reached at which, notwithstanding the high electromotive force available, no discharge through the residual gas can be detected. Thus, when one pole of a battery of 8,040 cells was led to one of the terminals of the tube, which has a radiometer attached to it, the other terminal of the tube, distant only 9·1 inch, being connected through a sensitive Thomson galvanometer to the other pole of the battery (earth), the current observed was not greater than that which was found to be due to conduction over and through the glass. Although no current passed, the leading wires acting inductively stopped the motion of the radiometer, as has been observed by Sir William Grove.

3. All strata have their origin at the positive pole. Thus, in a given tube, with a certain gas, there is produced at a certain pressure, in the first instance, only one luminosity which forms on the positive terminal; then, as the exhaustion is gradually carried further, it detaches itself, moving toward the negative, and being followed by other luminosities, which gradually increase in number up to a certain point.

4. With the same potential the phenomena vary irregularly with the amount of current. Sometimes, as the current is increased, the number of strata in certain tubes increases, and as it is diminished their number decreases; but with other tubes the number of strata frequently increases with a diminution of current. If the source of the current is a charged condenser, the flow being from one of its plates through resistances and the tube to the other, then, as the potential of the condenser falls and the current diminishes, the number of strata alters; if the strata diminish in number with the fall of potential, then the stratum nearest the positive wire disappears on it, the next then follows and disappears, and so on with others; if, on the other hand, the charge of the condenser is very gradually increased, the strata pour in, one after the other, in the most steady and beautiful manner from the positive.

5. A change of current frequently produces an entire change in the color of the strata; for example, in a hydrogen tube from a cobalt blue to a pink. It also changes the spectrum of the strata; moreover, the spectra of the illuminated terminals and the strata differ.

6. If the discharge is irregular and the strata indistinct, an alteration of the amount of current makes the strata distinct and steady. Most frequently a point of steadiness is produced by the careful introduction of external resistance; subsequently the introduction of more resistance produces a new phase of unsteadiness, and still more resistance another phase of steady and distinct stratification.

7. The greatest heat is in the vicinity of the strata. This can be best observed when the tube contains either only one stratum, or a small number separated by a broad interval. There is reason to believe that even in the dark discharge there may be strata, for we have found a development of heat in the middle of a tube in which there was no illumination except on the terminals.

8. Even when the strata are to all appearance, perfectly steady, a pulsation can be detected in the current; but it is not proved that the strata depend upon intermittence.

9. There is no current from a battery through a tube divided by a glass division into two chambers, and the tube can only be illuminated by alternating charges.

10. In the same tube and with the same gas a very great variety of phenomena can be produced by varying the pressure and the current. The luminosities and strata, in their various forms, can be reproduced in the same tube, or in others having similar dimensions.

11. At the same pressure and with the same current the diameter of the tube affects the character of the discharge and the form and closeness of the stratification.

THE ELECTRIC LIGHT.

THE Committee of the House of Commons appointed to inquire into the value of the electric light has completed its labors and has issued its report. There is no doubt that the evidence given before it, when published, will be very useful, and that the report itself is a careful digest of the facts elicited, but it is questionable whether the results of the inquiry, or the conclusions of the committee, will satisfy any one. Our readers will find in it nothing new. Gas engineers will find in it their extermination calmly contemplated. The gas manufacturer is told that he has nothing whatever to do with electricity. Gas, and nothing but gas, is his ware. Though he was incorporated to illuminate a city with the then best known illuminant, he is not to touch a newer illuminant because he will check the development of the fresh source of light, and his present mode of production is quite different to that required for the new commodity. It is as though a wine merchant who had a large sale of sherry were not allowed to sell beer, or a dairyman were not allowed to sell asses' milk because he only kept cows. The enunciation of such a proposition in a Parliamentary report is sad. Worse than all, municipal authorities are advised that they can ruin all the gas interests without the distribution of any compensation whatever. Surely the enormous capital sunk by the public in gas enterprise, deserves some consideration from its representation in Parliament assembled. Are our vestries and corporations so immaculate that they are to have entire control of our supplies of water and of light? Why not give them the supply of fuel and of heat? The line must be drawn somewhere, and it is well that Parliament should hesitate in the complacency with which it now thrusts on irresponsible communities the distribution of vital necessaries.

The only sphere in which electricity has made itself useful and practical as an illuminant is in our lighthouses, and though it is eminently adapted for nautical purposes, as ordinary ships' light, or to illuminate the sails of a ship, the report is silent on the point and on the absurd restrictions which have been placed by the Board of Trade on its use at sea.

The statement that the energy of one-horse power, when converted into gaslight, only gives 12-candle power, and into electric light 1,600 candle power, is startling if true. Without the evidence before us on which this statement is made, we cannot well contravene it, but it seems based on some fallacy. We remember seeing somewhere, but cannot recall where, a somewhat similar estimate, but it was based on the assumption that the whole of the coal was consumed in producing gas, and no allowance was made for the coke, tar, and other products of distillation. Is it so in this instance? Though 3 pounds of coal consumed in one way may give one horse power, and in another way 12-candle light, it by no means follows that one-horse power is equivalent to 12-candle gaslight—for in the case of gas we do not know the remanent energy.

The report fully confirms the opinion we have frequently expressed that the electric light sensation was due to a scare and not to any real progress or new discovery made. The transmission of power for mechanical purposes is foreign to the inquiry, and the suggestion that currents used by day for mechanical purposes can be used at night for illuminating purposes assumes what we only wish were true, that there is no mechanical work done in England in hours of darkness.

The general conclusion arrived at is that we can do no more with the electric light at present, but that we must do nothing to restrict its development. We did not require a Parliamentary Committee to tell us that.—*Nature.*

THE TELEPHONE IN CHICAGO.

IT is only last July—less than a year—since the first telephone was put up in Chicago. The American District Telegraph Company now has over fifteen hundred patrons—that is to say, it has put up that number of telephones with the corresponding number of wires. The carbon telephone constructed by Edison is used. The company has a central office and nine branch offices, which take in nearly every portion of the city. At its central office and branches the number of messages per day average 20,000. The demand for the telephone may be inferred from the fact that the American District Company has forty-seven men and five teams constantly employed in putting up new lines and instruments, and twelve others who are constantly engaged in keeping the lines in repair.

The exchange room of the American District Company is located on the upper floor of a lofty building on La Salle street. As one enters it, there is suddenly encountered a bewildering aggregation of sights and sounds, which takes time to separate into comprehensible details. Along the center of the room runs a framework which consists of a broad bench like foundation, and upon this a something which resembles an enormously high and long board set on its edge. The foundation is about three feet high. The boardlike structure—known as the switch board—is composed of a light framework carrying a metallic surface. From the ceiling there descends to this framework a perfect cataract of wires, looking very like the warp which descends to a loom. The similarity to a loom is increased by the fact that on one side of the metallic structure, or switch board, dozens of nimble fingered operatives are handling incessantly long, parti-colored threads, which they are placing, removing, twining over the metallic surface as if they were engaged in placing the "filling" for the warp that streams down from the ceiling. They are weavers—but their deft fingers are manipulating the lightnings, which, each moment, they are swiftly weaving into speech.

The racket is almost deafening. Along one side of the room are some mysterious instruments, shaped somewhat like the £ mark, which are constantly bursting with great energy into spasmodic clicking. There are telephone boxes all around the room, into each of which some man or woman is saying incessantly, "Hullo!" and "All right!" There are speaking tubes running all about the room, which look not unlike small stovepipes; and at one end and the other of these are placed the lips of one operator and the ear of another. Boys and girls are rushing madly hither and thither, seemingly without intent or direction; while others are putting in and taking out pegs from the metallic surface of the central framework as if they were lunatics engaged in an old-fashioned game of fox and geese.

Let us trace a communication from its source to its terminus. John Smith, druggist, has an Edison telephone in his office. Below and detached from it is a dial, about the circumference of a saucer, with a pointer, and certain letterings around the exterior surfaces. One of these says "Carriage," another "Doctor," a third "Messenger," a fourth "Police," and a fifth "Telephone In," and a sixth "Telephone Out." Mr. Smith does not wish a doctor or a carriage or a policeman, but he does wish to ask Quassia & Co., the wholesale dealers, four miles away in another part of the city, to send him over a few pounds of catnip, some barks, and hydrarg. He therefore places the pointer on the dial so that it points to "Telephone In," and then pulls back a short lever that is behind the dial. The lever slowly returns to its place, with a great racket, as if it were a runaway clock; and almost immediately thereafter the bell on the top of the telephone commences to ring. Thereupon Mr. Smith puts the receiver to his ear, and his lips to the mouthpiece of the transmitter, and the following conversation ensues:

"Hullo!"

"I want to be put in communication with Quassia & Co."

"All right!"

A moment later there is another clatter on the part of the little bell, and then another thrilling conversation:

"Hullo!"

"Hullo!"

"What do you want?"

"Who's at the pipe?"

"Blister, of Quassia & Co."

"Ah, all right. I'm John Smith. Send me two dozen sheaves of catnip, etc., etc."

"All right."

Mr. Smith then turns the pointer to "Telephone Out," pulls back the lever, and goes on with other business.

Over to the central office, when Mr. Smith first pulled the lever, one of the £-shaped machines instantly started to ticking furiously, and as it did so, unrolled a long, narrow slip of paper, upon which, in dots and dashes, appeared the number 253. An attendant watching out for such irruptions on the part of these eccentric machines, glanced on the paper, saw the cabalistic 253, whereupon he seized a thread-wound, flexible wire, several feet in length, with a couple of brass plugs, one at each end. One of these he inserted into hole 253 in the metallic surface—which hole indicates the termination of the wire coming from Smith's establishment—and the other he connected with a telephone in front of him. He had now a wire running direct to Mr. Smith, whereupon he touched a little knob which notified Mr. Smith, and then he proceeded to say to that gentleman: "Hullo." Informed of Mr. Smith's wishes, he remarked: "All right," placed one plug of the flexible wire in 1,608—Quassia & Co.'s number—the other in 253, and then notified the latter that the connection was made, and that he now had a line all to himself running to the establishment of Quassia & Co. A few minutes after the £ machine had another spasm, and dashed off two dashes, which was the response from Mr. Smith's "Telephone Out."

This is substantially the process of communication by telephone. It seems very plane-sailing, and is, as a general thing. Often, however, it happens that when an attempt is made to communicate with Quassia & Co., it is the case that somebody is already talking with them; and that a dozen others are waiting for an opportunity to do the same thing. Apart from these delays, which are inevitable, the time required to secure communication is only a few seconds.

The automatic registers, the £-shaped machines, which signal the call, are the invention of Mr. L. B. Firman, the manager of the district; and who in other respects has shown himself as ingenious in invention as he is competent in management. Not less than forty employes are kept busy in this exchange room in answering calls and establishing connections. In the sub-districts there are as many more, so that eighty attendants are required for this one branch of the telephone service.

There are many other details of the service that would be interesting, but which the limits of this article will forbid mention. It may, however, be added that in this central office the various railways have an exchange board all to themselves; that there are many private wires put up which simply connect a telephone in one place with some other telephone in another place; that for placing the telephone service in a person's place there is no charge, but one of $75 a year for its use, and that the wires used are galvanized iron, weighing about one hundred and sixty-eight pounds to the mile.—*Chicago Times.*

ELECTRIC LIGHT CARBONS.

To prevent the too rapid combustion of the carbons in the electric lamp Prof. H. W. Wiley, of Purdue University, Indiana, covers the carbons, previously copper plated, with a film of plaster of Paris. After the plaster is firmly set it is carefully removed from the edge of the carbon turned toward the lantern condenser and cut away until quite thin on the adjacent surfaces. The copper surface at the end of the carbon being uncovered, it is fastened in the holder in the usual way. Carbons thus prepared, he says, will last at least ten times as long as those made in the ordinary manner.

GAS AND GAS MAKING.

I.

By L. P. GRATACAP, Ph.B.

THE average householder, partly from tradition, partly by inherited prejudice, and partly through personal grievances and misunderstanding, regards the gas company who supplies his dinner table, his parlors, and his bedrooms with light, as an exorbitant monopoly, commissioned to impose upon its consumers, and to be resisted in any way, as invention or shrewdness dictates. Gas is somehow classed with sunlight and air, a universal element upon the use of which no artificial restraints should be laid, and which belongs quite naturally to any one who can or cares to use it. When the announcement of Edison's discovery of a cheap and brilliant substitute was made, a perceptible thrill of exultation went through the community. Surely, Edison has much to answer for if he wittingly deceived his admiring audience, and, after promising them emancipation from an unnatural yoke, and luring them into a distempered glee, now permits them to return to an odious bondage and a discarded nuisance.

Much, perhaps, of this ill-natured criticism of gas companies arises from an insufficient sense of the privileges gas bestows, its delightful assistance and protective influence; from ignorance of the amount of skill and invention that has been shown in the history of its improvement, and of the advanced state its manufacture has reached through persistent experiment. It is not to satisfy any profound craving after knowledge in gas making that we offer a general sketch of this industry, but rather to temper with a little reasonable information a surprising indifference as to what gas is or how it is made.

THE MATERIAL.

Not the least interesting topic connected with this subject is the material which yields the gas, and which, in whatever relation it is discussed, chemical, geological, or botanical, is one of the most remarkable objects offered to human study. It is coal. Those black, sightless heaps of grimy stone which fill the bins of our coal yards, represent the pivotal bearings of a nation's wealth. In other words, the heat that keeps winter from our door, the motion that carries us over hill and dale, the agency by which our ores are made to yield the sinews of commerce, and the cheerful flame that renews day in the night, all proceed from coal. The half-expressed apprehension of her statesmen that in 300 or 400 years England's supply of coal will become exhausted, and with its decline her naval and industrial supremacy disappear, strikingly illustrates the pre-eminent role King Coal may yet play in history. America views her own immense coal beds with complacency, and sees in them a sort of fore-installment of means ample enough to develop her enormous mineral resources and assist in the continuous growth of that of other peoples. The coal-bearing area of the United States, as compared with the available areas of other countries, is shown in the following table, quoted from Le Conte:

United States	120,000	sq. miles.
British America	18,000	"
Great Britain	12,000	"
Spain	4,000	"
France	2,000	"
Germany	1,800	"
Belgium	518	"

But how directly related the industry of coal mining is to the growth and development of the nation, and how the tables of its production are in a way criteria of the country's condition, is seen from the adjoined valuable statement:

Countries.	Yield in 1855. Million tons.	Yield in 1875. Million tons.	Percentage increase.
United States	5	50	900
Great Britain and Ireland	66	132	100
Germany	8	50	462
France	7·5	17	126
Belgiunf	8	15	88
Austria	2·5	12	380
Russia	·5	1·5	200
Australia	·25	1·5	500
Spain	·25	·75	200

This increase of 900 per cent has been largely due to rapid and abnormal increase in population, to a change from wood fires to coal fires, a cause which has similarly operated in Germany and Austria, to an enlarged consumption of fuel in living, manufactures, and railroads.

What is coal? Thanks to a long series of minute investigations we are able to answer this inquiry with considerable confidence. It was plants that contributed their parts, whether branches, leaves, twigs, bark, spores, or roots, to form extended layers of vegetable matter, which, collected after many seasons of decay and growth over immense flats, barely emerged from the waters of adjacent seas, or in swampy basins, built up seams of woody fiber that, through subsequent alteration, made our coal veins. Mr. Wunsch, of the Glasgow Geological Society, says that, from personal observation on the Isle of Arran, three to four inches of coal represents twenty generations of trees, and that in one foot of coal is condensed the vegetable debris of eighteen centuries.

Four genera of plants were prominent among—indeed, almost solely composed—the vegetable life of that time, enjoying a wonderful vitality and vigor, contrasted strangely with the meager subsistence of their modern relatives. These plants were ferns, equisetæ or horse tails, sigillaria and lepidodendra. The ferns, like the low-waving forms whose fronds adorn our rock gardens, and others, whose size resembled the tree-like proportions of the tropical species, mingled together in the woods. Great numbers of their fallen sprays and delicate leaflets are preserved on the floors and roofs of the coal seams, and impressions left over slabs of stone, formerly a plastic mud, which faithfully stereotyped every detail, acquaint us with the species that then flourished.

But much above these in importance, and more remarkable in appearance, were the lycopods, the lepidodendra, and the sigillaria. These plants were closely related to each other, and were identical in functions and general type of organization. The sigillaria, or seal tree, has contributed in large part its bark, branches, and especially its cellular core, which formed a pithy axis throughout its trunk and superior divisions, to the formation of the Nova Scotia coal, as revealed by the microscope to Dr. Dawson. Dr. Dawson says: "These trees present tall pillar-like trunks, often ribbed vertically with raised bands, and marked with rows of scars left by the fallen leaves. They are sometimes branchless, or divide at top into a few thick limbs, covered with long rigid grasslike foliage.

The lepidodendra were larger, more striking, and more attractive plants. Their branches were more numerous, forked, and with slender leaves wound around them in continuous spirals. These at first clothed the trunks and limbs, but as the tree expanded and rose they shriveled from the older parts, leaving lozenge-shaped scars in a quincunx order, whose form has offered an artificial and useless indication of specific differences. Many species made according to this mistaken criterion are really parts of the same species, being frequently but outer or inner bark.

These trees, multiplying their awns by their peculiar style of division (dichotomy), waved a forest of their leaves and flexible branches through the air of the carboniferous day, rapidly absorbing the carbonic acid about them, which, decomposed by the sun, fed their increase. Noticeable among these leaves were the lepidostroba—cone-like bodies enveloped in imbricated sheathing scales—which contained the spores or seeds for new plants. When ripe their dispersion took place much as the winged seed of our pines filter out from the pine cones and shower in clouds upon the ground. These minute sacs of the lepidodendron, though only 1-20th of an inch in diameter, actually constituted the bulk of large deposits which carbonized now form some of the best English coal. Modern instances are not wanting, affording some corroboration of this remarkable assertion.

In Invernesshire a shower of fir pollen occurred which hid the ground about for miles and in places was half an inch thick. Immense palls, traveling with the wind, have hid portions of the sky to observers in Virginia and North Carolina, which proved, after investigation, to be clouds of pine seeds. A more interesting parallel is found in the tasmannite of Australia. This is a shale, six to seven feet thick, and miles in extent, highly resinous and burning readily. The microscope shows the presence of numerous spores, sacs, and their accumulation in these schists has rendered the beds bituminous and combustible.

The last important member of this carboniferous flora was the calamites or equisetæ. These were rush-like canes, growing very high, bearing whorls of leaves at regular intervals, and tapering to a narrow and acute summit, tufted with crowded clusters of smaller leaves. They are related to the scouring rush, whose silicious stypes make a cheap sapolio to the rural housewife. They grew in hedges along the margins of low levels, and arrested the invasion of drift and sand over the interior country where the sigillarias and lepidodendra were storing up in comparative purity the fuel of the future. These plants collectively have furnished a great part of the material for our coal, their contributions far preponderating over the slight additions furnished by pines and cycads. Their luxuriant vegetation was grouped in swampy and extended basins, low troughs, and estuarine flats, scarcely elevated above or insecurely separated from the sea, and subject to occasional incursions of the latter, which hid, at each successive overflow, the new accumulations, and sealed them up in recurrent strata. They heaped up mouldering and rotting trunks, leaves, branches, and spores, which afterward were compressed by a weight of sand and mud, consolidated by heat, and metamorphosed by the alembic power of chemical forces. Thus was prepared from the sodden, rank, and fermenting layers the hard and soft coals which fill our coal scuttles, blaze on our hearths, and feed, by tons, the fury of our furnaces. Along with these towering club mosses, and, probably, composing a ground tier from which they rose, enormous stretches and mires of peat bog were engaged, century by century, in preparing deposits of vegetable fiber many hundred feet deep. Lesquereux says: "In ancient peat bogs, the peat especially near the bottom becomes black, compact, intermixed by layers of crystalline, though still soft coaly matter, which only wants hardness to be comparable to true coal or even undistinguishable from it." The essential importance of peat in coal making may be judged from its present utility in supplying a primitive fuel and its local extent. It is used as a substitute for coal in Ireland, Germany, Switzerland, America, and Sweden, and in Indiana covers one area three miles wide, sixty miles long, and varies from five feet to fifty feet in thickness

It does not seem necessary to presuppose an atmosphere essentially diverse from our own, though it was once thought that carbonic acid, the food of plants, should have far exceeded its present proportions in the carboniferous age, to provide for the enormous appropriation of it by the rank vegetation. Yet, although there are but three to four parts of carbonic acid at present in 10,000 parts of air, there still rest over each square mile of the earth's surface 1,300,000 tons of this gas, containing 371,475 tons of carbon, and but the slightest increment would raise these figures astonishingly. Surely, here is reason enough to warrant our rejecting the prevalent conception of the necessity of a noxious atmosphere, crowded with this irrespirable gas, in the days of the coal measures. Moisture, however, abounded, the air was heavy with humidity, frequent and long rains watered the luxuriant forests, and hot fogs enveloped, at times, the highest trees. The climate was equable, and since we do not find in the remains of exogenous trees any rings of growth, it has been concluded that growth was continuous and not annually intercepted by cold winters.

The thickness of the coal seams varies from thin films to strata forty feet in thickness, though, in most instances, impure beds lessen the workable veins of coal by many feet. These coal beds extend over wide areas, embracing thousands of square miles, they vary throughout their extent in thickness, the same seam thinning out almost entirely and thickening again to its greatest depth, illustrating the varying surface of the land, its depressions, its margins and drier parts, and the contrasted luxuriance and poverty of the vegetation.

The formation of coal from woody tissue can be chemically expressed with sufficient clearness to allow us at least to apprehend the stages of the process and the nature of the bodies whose disappearance from the original fiber leaves the carbonaceous residue known as coal. Wood is composed in its ultimate analysis of carbon, hydrogen, oxygen, nitrogen, sulphur, and other mineral constituents taken up by the plant from the soil. These elements are grouped in a form obscurely, if at all, understood, and the multiplex reorganization of these compounds in decomposition and slow burning up, which that implies, results in eliminating certain products of hydrogen, oxygen, and carbon, whose aggregate effect is to increase the carbon in the parts remaining. The abstraction of carbon, hydrogen, and oxygen takes place under the form of water, carbonic acid, carbonic oxide, marsh gas, and rich oils, which are for the most part collections of a vast variety of bodies made up of carbon and hydrogen combined in different proportions. The transition then of a wood to coal embraces a series of states, and could we arrest the action at various successive points we would discover the general tendency of the changes taking place, and probably, also, meet with a number of substances specifically distinct. In a rude way nature has done this for us, and we can arrange in a line a number of natural products, each of which represents a certain broad and comparatively permanent phase in the process, and conducts us from the raw material, wood, to the perfected product, anthracite or graphite. Such a scale would read, with its table of component parts, as follows:

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Wood	49·70	6·06	41·30	1·05	1.80
Peat	58·18	5·96	31·21	1·23	3·43
Lignite	67·00	5·55	20·35	2	4
Bituminous coal.	75	5	13	1	6
Semi-bitum. "	—	—	—	—	—
" anthracite	—	—	—	—	—
Anthracite	92	2	2	2	2
Graphite	100				

Of course, it must be understood that the above percentages of comparison are varied in every particular instance where a specific coal is examined, since the age of the coal, any peculiar circumstance of its formation, the plants or parts of plants that composed it, some modifications of the process of alteration, one or all produce corresponding variations in the result, so that the above table represents the most general average from numerous analyses and corresponds strictly with no single result. Yet the briefest inspection shows two things: first, a concentration and increase of carbon; second, a gradual disappearance of hydrogen and oxygen. To bring this latter fact into greater prominence, Prof. Thorpe has constructed a table where, by making the carbon constant, the removal of the hydrogen especially, and that of the oxygen also, gain an exaggerated effect.

	Weight of one solid cubic foot in pounds.	Carbon.	Hydrogen.	Oxygen and nitrogen.
Wood	30	100	12·3	86·8
Peat	50	100	9·7	54·7
Lignite	70	100	8·3	40·
Brown coal	75	100	7·4	29·7
Bituminous coal.	80	100	6·4	13·4
Anthracite	90	100	2·6	2·3

A closer examination of these substances will introduce a number of interesting facts.

The initial stage of the change of this vegetation into coal began with a complete or partial maceration and rotting of the woody tissue, accompanied or followed by a fermentation interfered with and impeded by pressure and protection from air. The albuminoid constituents of the wood start this putrefactive process, during which oxygen is absorbed and water and carbonic acid eliminated, while a rise in temperature indicates the combustive nature of the action. A stage must have been soon reached, which probably approached the state of things existent in vegetable mould, when the dark mouldy body, known as *humus*, is produced by decomposition, forming on the surface of ground a rich and efficient manure, and representing an intermediate step in the production of coal. Thus, the following table from Prof. Thorpe shows an increase of carbon and a removal of hydrogen and oxygen:

	Carbon.	Hydrogen.	Oxygen and nitrogen.
Woody tissue	50·2	6·2	43·6
Oak humus	54	5·1	40·9
" "	56	4·9	39·1
" "	55	4·8	39·9
Moss "	54	4·6	41·4
Average	54·8	4·8	40·4

It was due to this softening, which doubtless greatly varied in different places, and left the evidence of such local differences in the physical structure of the coals produced, that we find the trunks of sigillaria, ferns, and lepidodendra flattened whenever they were exposed to pressure, and their cellular cores squeezed out. Those trunks which preserve their rotundity are found in the middle of the coal veins; where the yielding and pasty mass found a cushion against external pressure.

The disintegration thus begun continues with precisely similar effects, concentrating carbon and, proportionately, discharging hydrogen and oxygen until peat-like bodies form. Peat bogs themselves show, in their vertical sections, the gradual gradations from the unchanged vegetable matter on the surface to dense and coaly layers on the bottom, where organic texture seems obliterated and a real coal encountered on the very verge of its actual production.

PEAT ANALYSES.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Philipstown, Ireland	57·52	6·83	32·23	1·42	1·99
Wood of Allen, "	58·30	6·43	31·36	1·22	2·74
Upper Shannon, "	58·53	5 73	32·32	·93	2·47
" " " dense	59·42	5 49	30·50	1·64	2·97
Average	58·18	5·96	31·21	1·23	3·43

It must be remembered that where the vegetable debris undergoes a stifled combustion, the products become more complicated, and, as under water, a release of both carbon and hydrogen takes place simultaneously in the form of marsh gas or carbureted hydrogen, the fire damp of mines, against whose frightful aptitude to explosion the safety lamp of Sir Humphry Davy and Ansell's indicator are both well known protections. It seems likely that the transition of peat coals to ordinary bituminous coals might have been effected by pressure; some slight degree of heat, and the continuous consolidation of fixed carbon and the formation of higher and higher homologues of marsh gas and olefiant gas, which, if not effectually existent in the coal, instantly group themselves out of more elaborate mixtures upon the application of heat.

The stage of lignite chemically succeeds that of peat, though it appears questionable whether all coals passed through its physical aspects.

Lignite is a fossilized wood, light or dark brown in color, of a woody texture, yielding vinegar or acetic acid upon dry distillation, friable and brittle.

ANALYSES OF LIGNITE.

	Carbon.	Hydrogen.	Oxygen and nitrogen.
Devonshire	67·9	5·8	26 3
Cologne	67	5·3	27·7
Washington Territory	69	7	24

Brown coal is an advanced state of lignite, wherein organic structure disappears and ammonia results from distillation.

ANALYSES OF BROWN COAL.

	Carbon.	Hydrogen.	Oxygen and nitrogen.
Tasmania	71·9	5·6	23·5
Auckland	73·2	5·4	22·4
Hungary	72·5	5·4	22·1

Prof. Thorpe says: "From the brown coal we pass by insensible gradations to the black coal or coal proper. The change is attended by an absolute loss of ligneous structure, by an increased density and a tolerably well developed cubical fracture." The bituminous coals forming the next substantial group, next to the brown, so far as chemical composition is concerned, are those rich coals, burning with a smoky flame, possessing a resinous luster, yielding large quantities of volatile products, and having a fracture more or less conchoidal. They vary greatly in composition, for they occupy that broad and intermediate position between lignites or peats and anthracites, wherein are found the progressional states of carbonization and molecular change from bodies with 50 per cent. of volatile matter, to others with less than 4. The elaborate structure of wood or cellulose, with which we started, has been profoundly disturbed, a wonderful reduction and a rearrangement of atoms have taken place, accompanied with the potential birth of a great number of bodies ready to escape in the form of vapors, tar, and gases, upon the application of heat."

Prof. Rogers, in the geology of Pennsylvania, classifies bituminous coals as follows:

Common Bituminous Coals.	Semi-bituminous Coals.	Semi-bitumin. cherry coal.
		" " splint "
	Bituminous Coals	Caking coal.
		Cherry "
		Splint "

The variability of composition in this class of coal is readily seen by a comparison of the subjoined analyses, selected from Barr's "Combustion of Coal."

	Mecklenburg Co., Ky.	Blossburg, Pa.
Fixed carbon	51	73·11
Gas	42·50	15·27
Water	2	
Ash	4·50	10·77
	Clay Co., Ind.	Cumberland, Md.
Fixed carbon	44	68·44
Gas	47·50	17·28
Water	4	
Ash	4·50	13·98

The examples from Kentucky and Indiana represent bituminous coals in the professional use of that term, while those from Pennsylvania and Maryland illustrate the average composition of semi-bituminous coals, though necessarily the distinction admits of no specific definition, as we can pass from one to the other through a scale of carefully graded states of carbonization. The behavior of this class of coals under the influence of heat assumes two very different aspects, and has, consequently, afforded a more or less useful means of classification. One class, known as caking coals, fuse when heated, emitting jets of gas, and becoming pasty from the generation of tar-like bodies which agglutinate the carbon particles, causing them to cohere in lumps and masses over the surface of the grate. The other class, known as non-caking coals, also as free burning coals, burn openly without melting and running together—a peculiarity, perhaps, attributable in a measure to a deficiency of tarry constituents and more to a difference in their physical condition.

As we pass beyond the states of carbonization seen in the series of bituminous coals, we encounter the semi-anthracite and anthracite coals, where a continuation of the same process of eliminating the volatile portions and increasing the carbon is carried out to its natural limits. These coals are very dense, requiring a large supply of oxygen for their combustion, generating a great heat, and burning with a low, blue flame. They form the coals most familiar to eastern eyes, their brilliant luster and stone-like weight and hardness giving them a characteristic unmistakable facies. The semi-anthracite coals contain somewhere from six to eight per cent. of volatile material, and the true anthracites only 2 or 4 per cent.

Although it is generally believed that the anthracites have attained their concentration of carbon and their compact vitrified structure through the action of heat upon the bituminous beds, previously occupying the present position of the anthracite veins, yet new evidence to the effect that coals become anthracite by exposure to the air at ordinary temperatures, opens up the question to further debate. In allusion to the prevalence of the anthracite along the Appalachian axis, Dr. Newberry remarks: "When special and local causes have operated to carry the change still further, as when the beds of coal have been involved in the upheaval of mountains and heat acted upon it, it is converted into anthracite." It is certain that heat effects this metamorphic action, as at Santa Fe, New Mexico, the cretaceous lignite is converted into anthracite by the intrusion of a dike of trap, formerly a molten channel of lava. Exactly similar alterations are known at Las Bronces, in Sonora, and on Queen Charlotte's Island, south of Alaska.

Besides the caking coals, which are properly considered gas coals, the cannel coals afford to the gas engineer the most important material for his manufacture of gas. Cannel coal is so called from its ready combustion in allusion to a candle, of which the name is a corruption; it is also called parrot coal, from the crackling noise it makes on the fire, suggesting the chattering of a parrot. It yields a large amount of hydrogen, and is properly a hydrogenous coal. The Breckenridge, Kentucky, cannel offers a good instance of this property.

PROXIMATE ANALYSIS.

Carbon	32
Volatile matter	54·40
Moisture	1·30
Ash	12·3
	100·00

ULTIMATE ANALYSIS.

Carbon	68·128
Hydrogen	6·489
Nitrogen	2·274
Oxygen and loss	5·833
Sulphur	2·476
Ash	14·8
	100·00

Cannel coal has been found under water, macerated pulpy masses of vegetable matter have settled to the bottom of some pool or lake, contributing to give it its fine homogeneous texture, and here the slowly evolved products of internal decomposition and combustion, through admission of the oxygen dissolved in the water, have shaped themselves, resulting in a fuel where the hydrogen bears a high proportion to the oxygen and nitrogen.

Dr. McFarlane thus summarizes the features of a gas coal: "The most important requisites of gas coal are, first, that it contains a large amount of volatile combustible matter or gas; second, that the volatile matter be of good illuminating power; third, that the coal be as free as possible from sulphur; and fourth, that the coke furnished by the carbonization of the coal be bulky and at the same time firm, that is, not inclined to be granular."

Though these facts form a very hasty sketch of the questions involved in the discussion of coal, yet they may assist in explaining the nature, origin, and characteristics of that mineral, which, besides being the basis of gas manufacture, has been termed "the source and guide of civilization."

[Continued from Supplement No. 186.]

PROGRESS OF INDUSTRIAL CHEMISTRY.

BRIEF REVIEW OF THE MOST IMPORTANT CHANGES IN THE INDUSTRIAL APPLICATIONS OF CHEMISTRY WITHIN THE LAST FEW YEARS.

By J. W. Mallet.

METALLURGY.

Nickel and Cobalt.—Within a decade the extraction of these metals has increased notably in importance; and the scale upon which they are worked has expanded greatly in consequence of their successful application in electroplating, while formerly nickel was scarcely used save in its alloys of the German silver class, and metallic cobalt was not in industrial use at all. Extensive search has been made in various countries for new supplies of ore, in the main resulting in bringing together small lots from different sources. Probably the most important single new locality is New Caledonia, furnishing, not the more common sulphides and arsenides, but the hydrous silicate of nickel and magnesium, known as Garnierite or Noumeite. The metallurgical processes in use are carried out partly in the "dry" and partly in the "wet" way. In the former direction there has been improvement, the result of experience in the concentration of poor ores, such as the nickeliferous pyrites, to mattes containing a much increased percentage of nickel, and the cobalt which may be present can be recovered in the state of oxide, to be subsequently reduced to metal, instead of obtaining it merely in the form of crude silicate, as "smalt" or "zaffer." The metallic nickel furnished to commerce is of higher purity than was known a few years ago, 98 or 99 per cent. of real nickel being easily obtainable, and even higher grades of product seen to some extent. Moreover, the small, irregular grains and the cubes of but half melted nickel which not long ago constituted the only forms in which the metal was turned out, have been largely replaced by solid ingots of various weights up to 5 or 6 kilos each, cast from crucibles in which, with the aid of well-arranged wind furnaces, the refractory metal has been completely fused.

Zinc.—The most noteworthy increase in the production of zinc of late years has occurred in the United States (New Jersey, Pennsylvania, Virginia, Tennessee, Illinois, Iowa, Wisconsin, Missouri), which may now be reckoned among the great sources of the world's supply.

The methods now and for a long time in use for the extraction of this metal from its ores still leave much to be desired; the various forms of distilling apparatus are complicated, more or less troublesome, and not adapted to continuous working; and much zinc is obtained by the burning of the metallic vapor in contact with air, or is deposited in a pulverulent form by too sudden cooling instead of condensing into liquid metal fit for casting into ingots. None of the attempts which from time to time have been made to devise a furnace capable of turning out, without serious loss, fused zinc by a continuous process, seem yet to have achieved success. The nearest approach to such success has been the continuous reduction and distillation of the metal with intentional combustion of the vapor, to produce zinc white for painters' use. It may possibly be worth consideration and experiment whether the volatilization of zinc might not be, at least to a large extent, prevented by reducing, under suitable conditions of temperature and furnace atmosphere, its ores along with those of lead, taking advantage of the fact, illustrated by the ancient method of making brass from copper heated with calamine and charcoal, that the presence of the less volatile metal in the alloy reduces notably* the volatility of the other; the subsequent separation of zinc and lead admitting of being effected, as far as much the larger portion of each metal is concerned, by liquation, as in the now common Parkes process for desilverization of lead. If such a reduction method could be given practical shape, any zinc vapor which did still escape might be allowed to burn and collected as zinc oxide for painting.

Tin.—The most prominent fact for some time past in the history of this metal has been the very large addition to our annual supplies since 1870 coming from Australia, while the product from the Dutch East Indies has also largely increased. The tin-bearing territory of New South Wales and Queensland covers several thousand square miles, affording already some ore from veins likely to be much more largely opened up in the future, but much larger quantities from magnificent washings of stream tin. Tasmania also affords some smaller additional supply. Most of the Malay tin of Banca, Billiton, the peninsula of Malacca, etc., comes from "dry diggings" in decomposed granite or pegmatite, the more or less disintegrated remains of feldspar or quartz being washed away, and the ore smelted on the spot in rude furnaces of small size with charcoal fuel, and a blast from the hollow trunk of a tree in which a piston works to and fro. Twelve or fifteen years ago the general supply of the world might have been set down in round numbers as—

Metallic Tin.	
From England (Cornwall and Devonshire)	8,500 tons.
" Malacca and the Malay Islands	7,500 "
" Saxony, Bohemia, and all other sources	450 "
	16,450 tons.

A similar estimate for the present time stands thus:

From Malacca and the Malay Islands	14,500 tons.
" Australia	10,000 "
" England (Cornwall and Devonshire)	9,500 "
" Saxony, Bohemia, Bolivia, etc., etc.	650 "
	34,650 tons.

* It would have to be determined by experiment how far lead can thus give fixity to zinc at the temperature necessary for the reduction of both and separation of slag.

This doubling of production has been attended with a corresponding fall in price—from £127 to £61 per ton.

There has been no material change in the simple processes of tin smelting. The application of Oxland's method of preparing the ore by getting rid of accompanying wolfram in the form of sodium tungstate has furnished some material for the utilization of tungsten compounds; most of the latter, however, so far as in use at all, are obtained from independently mined or mechanically separated wolfram.

Bismuth.—At the chief seats of bismuth production in Saxony and Bohemia, the old and simple process of extraction of the native metal from rock through which it is disseminated by liquation in slightly inclined cast-iron tubes has been abandoned, it being found that too much of the now quite valuable metal was left in the residues of imperfectly exhausted gangue. Instead, the mixed ores, largely associated with those of cobalt, are roasted and then reduced in the furnaces of the smalt works with additions of charcoal, metallic iron, and slag. Two layers separate after fusion, the upper one consisting of cobalt-speiss (arsenides of cobalt, nickel, and iron), the lower of crude metallic bismuth. The latter is run off in the still fluid state after the former has solidified, and the bismuth, cast into blocks, is refined by eliquation at a gentle heat on an inclined iron plate. Almost pure bismuth flows off, while the foreign metals with a little bismuth remain as dross to be worked over.

To a limited extent the ores of this metal have of late years also been worked in the wet way—as at Meymac in France, where a small supply of oxidized ore is treated by solution in hydrochloric acid and precipitation by water or on bars of iron.

There has been a remarkable increase of demand for bismuth within a few years, leading to increase of price, since although supplies of ore have been received from several new quarters, chiefly Peru and South Australia, in less quantity from Mexico, France, etc., the aggregate of these new receipts has borne but a small proportion to the amount furnished by the one long known and most important mining region of the Erzegebirge, of which Schneeberg in Saxony and Joachimsthal in Bohemia may be considered the two chief points. At present the annual supply is estimated as,

From Saxony and Bohemia	32 tons.
From all other sources	3 "
	35 tons.

of which much the largest part is devoted to the production of bismuth oxychloride and hydrato-nitrate for use in medicine and as cosmetics, most of the rest being employed in making readily fusible alloys and producing the shell-like luster on porcelain which has given rise to the name "porcelaine nacre."

Copper.—Amongst the countries which have added most to the general supply of copper for the last quarter of a century are Chili and South Australia; the mines of the former have of late increased, those of the latter diminished in productiveness. To these will probably ere long deserve to be added Arizona, where valuable ores are abundant, and possibly at some later day Northwestern Texas. The product of the Lake Superior region has assumed an important place.

The general course of copper smelting has undergone no great change for a long time, though there have been local variations of practice, due chiefly to special supplies of ore requiring particular treatment, and to the establishment of new seats of the industry. Swansea no longer fully holds the position of supremacy it formerly enjoyed, but the tendency is still marked toward the concentration of ores, and, of late years, of mattes and crudely smelted regulus of copper, at this and a moderate number of other centers, there to be treated with all the advantages of skilled labor, suitable and abundant fuel, etc. The most remarkable proposal of a new method of furnace treatment is that of Mr. Hollway, very recently brought before the Society of Arts of London, looking to the application of the Bessemer blast of air to sulphides in a melted state, the temperature being maintained simply by addition of fresh quantities of ore. Too little is yet known of the results even of such experiments as have been made for an opinion to be formed of the probable value of the idea; some advantages at once suggest themselves, but there are also manifest difficulties, such as the effect of the presence of much silica and the risk of loss by volatilization.

Relatively, much greater extension of processes in the liquid way has occurred of late years than has characterized the furnace methods. The very large use now made of the sulphur of more or less cupriferous pyrites in the manufacture of sulphuric acid has furnished abundant material, and the saving of the copper contained in burnt pyrites residues has become a regular subsidiary industry, especially in England, where in 1875 no less than 9,600 tons of the metal were thus produced, several thousand pounds' worth of silver and gold being also obtained from the same source. The main features of the process consist in calcination of the spent pyrites mixed with common salt in furnaces often heated by gaseous fuel from a Siemens generator, leaching with water, and precipitation by metallic iron, preferably used in the spongy state obtained by reduction of some of the exhausted pyrites in a muffle furnace with ground coke.

In the United States the introduction of the Hunt and Douglas wet process should be particularly noticed—its wide range of applicability to ores of different kinds is one of its prominent merits. The material to be treated, roasted at a gentle heat if necessary to remove sulphur or decompose carbonate, is exposed to the action of a mixed solution of ferrous chloride and sodium sulphate and chloride,* this being used either cold, or, with a view to more rapid effect, in a heated state; the undissolved residue is washed with a further portion of the same solution (hot); and from the mixed liquids obtained the copper is thrown down by metallic iron, reproducing the original solvent to be used over again. Taking only the case of the copper present as cupric oxide in the roasted ore, the reactions are essentially,

$$3CuO+2FeCl_3=Cu_3Cl_3+CuCl_3+Fe_2O_3,$$

the cupric chloride dissolving of course in the water used, while the cuprous chloride is rendered soluble by the presence in the liquid of ferrous and sodium chlorides, and

$$CuCl_3+Cu_3Cl_3+Fe_3=Cu_3+2FeCl_3.$$

This method has been successfully used with copper ores (simply), both of the oxidized and sulphurous classes, and also with ores containing the precious metals, these latter being obtainable from the residues after the copper has been removed by leaching.

* Obtained by the addition of common salt in excess to solution of ferrous sulphate.

The more careful examination which submarine telegraphs have led to of the great influence upon the conducting power of copper wire for electricity, of impurities occurring to even a very minute extent, has stimulated the production of much purer copper than could readily be had ten or twenty years ago, and hence copper refining has assumed an increased degree of importance, and commands increased attention and care.

Lead.—Among the greatest recent additions to the sources of supply of this metal must be counted the argentiferous and auriferous lead ores of the Rocky Mountains and outlying ranges to the eastward of the Sierra Nevada, especially in Colorado, Utah, and Nevada, where galena and cerussite have been discovered and worked upon the grandest scale, the precious metals present often causing the lead to assume but secondary importance, while in the aggregate this latter possesses immense value. The same regions, speaking broadly, afford also vast quantities of iron and copper pyrites, and zinc blende; from the working of these for gold and silver much copper is saved, chiefly in mattes to be worked over elsewhere, while the great bulk of the zinc is lost.

In connection with the working of these ores, though of course applicable to and in practice applied to those of various other kinds, may be noted as capital improvements in mechanical treatment the use of the "Blake Crusher," the invention of Eli W. Blake, of New Haven, Conn., for breaking down the ore to small fragments, the steady mastication effected by which is in marked contrast with the slow and power-consuming work of the old fashioned crushing rolls; as also the substitution, for reduction of the crushed ore to powder, of stamp batteries made wholly of iron, with well proportioned and well finished parts, for the more clumsy constructions, partly of wood, which were formerly in use. Direct-acting, steam-driven stamps have also been brought into use, but to no large extent on account of their greater liability to need repairs at the hand of the skilled machinist, not always available in rough mining regions. Many valuable contrivances for the dressing and concentration of ores have also been added to the older arrangements.

In the chemical treatment of lead, as well as other ores, improved forms of roasting furnaces have proved of much value, particularly those of the type represented by the Gerstenhöfer and Stetefeldt furnaces, in which finely pulverized ore is fed in at the top of a red-hot shaft of fire-brick, down which it drops, encountering on the way an upward current of highly heated gases, partly the products of combustion from the fireplaces, but including an abundant supply of surplus atmospheric oxygen. These more modern furnaces have in a measure taken the place of the simple reverberatory for roasting, while for smelting the roasted ore this latter has also to a considerable extent been supplanted by small blast furnaces, in the construction of which hollow cast-iron walls traversed by a current of water—water-jackets—are coming into more general use than formerly, replacing the fire-brick linings, which in some regions are procurable only from a distance and at heavy cost. The very general introduction of processes for desilverization, although of primary consequence in relation to the saving of the precious metal, has resulted also indirectly in softening and improving the character of the average lead of commerce.

Mercury.—As regards the supply of this metal, for which the demand has been greatly extended by the expansion of gold and silver mining within the last thirty years, the great fact has been the discovery of Californian cinnabar* upon a scale placing the United States first among the countries producing mercury, while not inconsiderable through irregular supplies have been received from Borneo. The present annual production may be set down in round numbers as—

From California	2,363 tons	(of 2,240 lbs.)
" Spain (Almaden)	1,424	"
" Austria (Idria)	273	"
" all other sources	263	"
	4,323 tons.	

The metallurgy of mercury still continues in a very unsatisfactory conditon, the loss being enormous, while the low price at which alone the metal can now be sold ought to prove a stimulus to more economical management of the reduction. At present it is estimated that the best results are obtained at Idria, where nevertheless the loss is 30 per cent. on the amount of metal shown by assay to be present; in California there is an average loss of something like 40 per cent., while at Almaden, in Spain, it is set down as 50 to 53 per cent. To this immense waste must be added the large quantities afterwards lost in use, gold and silver amalgamation processes involving the sweeping down to the rivers of very much finely-divided mercury and its compounds, never to be recovered by any practically available means.

The chief sources of loss in reduction are, first, imperfect heating of the larger fragments of cinnabar-bearing rock, so that portions of ore remain unacted on in the interior; and, second, imperfect condensation of the vapor, which escapes from cracks and defective joints of the furnaces and passes through the porous masonry of their walls. The latter of these causes of loss is the more serious in the extent of its results. Attempts to obviate it, such as that made many years ago in the Palatinate, under the direction of the late Dr. Ure, by using vapor-tight retorts of cast-iron heated from the outside and retaining the sulphur by means of lime, involve increased difficulty from the first mentioned cause, since the heat has to penetrate the semi-diameter of the retort as a whole, and the volume of material heated is swollen by the addition of the lime, while no heat is obtained from the combustion of the sulphur. The same remarks apply to the bell-furnaces of Bohemia, in which reduction is effected by means of iron or "hammerschlag." Using such arrangements with poor ores—and the great mass of the ores usually available are poor—the consumption of fuel is extravagantly large, and the iron vessels are rapidly destroyed, or much cinnabar escapes reduction. In the brick-work furnaces used at all the most important seats of mercury production the sulphur is burned off by the oxygen of the air, producing much of the necessary heat, though Californian experience seems to have shown that there may be an unwise economy of outside fuel, it being well to supply, by means of such fuel burned in separate fireplaces adjoining the hearth space occupied by the ore, ample heat to insure the thorough expulsion from the rock of all mercuric sulphide. The great difficulty, however, arises from the escape of uncondensed vapor of mercury, the masonry and the underlying soil bearing ample testimony to this in the large quantities—thousands of pounds sometimes—of irregularly condensed metal found soaking through the porous material when old furnaces are taken down.

The most hopeful line of improvement seems to be that of a combination of all the safeguards which have individually proved more or less efficacious, along with perhaps some others which may be suggested, small in themselves but likely to prove useful in detail, say some such general arrangement as the following: 1st, detached fireplaces with grates adapted to the combustion of the fuel used, delivering their gaseous products of combustion into—2d, hearths for the reception of the properly piled ore, to be constructed of an outer shell of cast iron plates put together with planed flanges and screw bolts, or else of heavy riveted boiler plate made as vapor tight as possible, with a thick interior lining of fire brick; 3d, a first set of condensing flues leading from the hearths, also of heavy cast iron, brick lined only so far as the high temperature extends, with sufficient number of such flues and subdivision of cross section to give extensive cooling surface; 4th, a second set of flues, extensions of the first, of stout Russia sheet iron, well asphalted inside and out by immersion at a temperature just short of redness in boiled coal tar, to resist the corrosive effect of the sulphur acids formed; 5th, a system of pipes for the injection of cold water spray into the condensing flues, and well arranged drip pipes to carry off *promptly* liquid water and condensed mercury; 6th, an effective exhauster to produce forced draught through the flues irrespective of the temperature within them, and to prevent the tension of the contained gases ever exceeding the atmospheric pressure without. The same set of condensers might be worked with several fireplaces and hearths if intermittent firing be practiced, but with detached fireplaces it does not seem difficult to provide for continuous working by means of well fitted and vapor tight doors to the hearths for the discharge of burnt out ore and the introduction of fresh.

Silver.—In this country it is needless to more than refer to the immense additions to the world's stock of silver which Nevada, Colorado, and other far Western States have made within twenty years, treasure comparable with and even exceeding the flood tide from Spanish America in its period of greatest prosperity. In Europe the importance of the results obtained and their influence on present problems of finance and political economy, seem scarcely to be well understood by the general public, though no doubt familiarly known to many of those who concern themselves about such questions.

In various mining districts of the world, but notably in this region of new and great activity in the United States, there have been modifications in all three of the classes into which the processes for reducing silver from its ores may be divided.

1. *Amalgamation processes, involving the collection of the silver, however first reduced, by solution in mercury.*

Certain ores are found to be adapted to immediate amalgamation, while others cannot be thus profitably worked unless first roasted, either alone or more usually with an addition of common salt, in order to produce silver chloride. For the purpose of this roasting, as with other like objects in view in the treatment of the ores of other metals above alluded to, new forms of furnaces, such as the Stetefeldt, have come into use and have to a large extent replaced the time honored reverberatory. The rotating hearth, as in Brückner's furnace, providing for constant stirring of the material treated and the exposure of new surfaces to the hot gases and air from the fireplace, has in some hands given valuable results in application to this preliminary roasting.

For the amalgamation itself, the classical Freiberg process, carried out in revolving wooden barrels, is no longer in use at Freiberg itself, having been given up a few years ago; it is still employed elsewhere, however, as in Chili, and up to a short time ago, at least, at a few works in the United States. The ancient Mexican or *patio* process, the invention of Fray Bartolomé de Medina in 1557, still holds sway throughout most of Spanish America. Its place has been taken in this country by the introduction within a few years of the so called "Washoe" process of amalgamation in cast iron pans. These shallow cylindrical or slightly conical pans may be considered as improved forms of the old fashioned Chilian mill or "arastra," replacing the clumsy blocks of stone dragged round in a stone trough by mules or oxen, by a machine entirely of iron, having well proportioned scrubbers or mullers shod with easily removable plates of chilled iron revolving upon similar plates set in the bottom of the pan, and provided with the means of adjusting the distance between the grinding surfaces. Sometimes the bottom of the pan is steam jacketed in order to permit heating the charge during amalgamation.

Sometimes the only materials introduced are ore, water, and mercury; in which case native silver is simply taken up into solution by the mercury, while the chloride, bromide, and even sulphide of silver are more or less effectually decomposed by the iron of the pan and by the mercury itself, the reduced metal being then also dissolved to a fluid amalgam. At other works "chemicals" are added to the contents of the pan, these consisting mainly of cupric sulphate and common salt, essentially the same materials as have long been used, the former in the impure shape of "magistral," in the "patio" amalgamation. The ore is placed in the pan in the state of subdivision in which it comes from the stamps, but is more finely ground during the amalgamation, especially during the first part of the process. Transferred to a generally similar pan known as the separator, but with the addition of much more water, the pulp is stirred round and round until the amalgam separates at the bottom and the soluble matter and great mass of silicious and earthy material from the gangue can be washed away, the amalgam being then drained of fluid mercury (holding a little silver in solution) and heated in an iron retort to drive off the rest of the volatile metal. In this process, greatly improved as it is in contrast with patio amalgamation on the score of time and labor consumed,* and in spite of the advantage gained by experience as to details in its application, there is still much room for further economy, the loss being large in absolute value of the precious metal, either not chemically separated from some of its compounds in the ore (imperfect reduction), or not mechanically separated as amalgam from the "tailings" which are washed away (imperfect collection). The value of the mercury also lost is in the aggregate important, some of it losing its metallic form, as it serves as the means of reducing the silver by taking up chlorine, sulphur, etc., some of it being as finely divided metal mechanically washed away.

2. *Smelting processes, involving the reduction of the silver by furnace means, and its collection in solid alloy with one of the baser metals, usually lead, sometimes in the first instance copper.*

The use of improved forms of furnace for both roasting and smelting lead ores has been already alluded to, and their merits have been tested on a large scale in the treatment of the argentiferous sulphide and carbonate found in such abundance in some of the States in the far West. The further treatment of the "base bullion" or argentiferous lead produced, with a view to the separation of the silver, requires now to be noticed.

The original invention of Pattinson of Newcastle, patented in 1829, for desilverization of lead, depends upon fusion of the metal in somewhat large mass, slow cooling, and removal with perforated ladles of the lead crystals as they solidify, repeating the process several times with the refused crystals on the one hand, which become poorer and poorer in silver, and with the residual lead on the other, this increasing in value up to a certain point, when it is cupelled. This mode of working has of late been modified by Rozan, a jet of high pressure steam being passed into the bath of melted metal, stirring it up and exposing fresh surfaces to the air, so as to promote the oxidation and removal as dross of antimony, copper, etc., while the steam, as it condenses, leads to more regular crystallization than attended the older method. Hydraulic cranes are used in transferring the lead, doing away with much of the arduous hand labor formerly required. The results are favorably reported.

To a large extent, however, for some years past the process known as that of Parkes has been substituted for the ingenious invention of Pattinson. Zinc is added (1-5 per cent.) to the melted lead to be desilverized, the temperature being raised above the fusing point of zinc, and the two metals are well mixed by agitation. A prolonged period of repose follows, extending to several hours, during which the temperature is allowed gradually to fall, so that the zinc separates out on the surface in solid form, carrying the silver with it. The zinc is removed and afterwards distilled off in flask-shaped retorts of plumbago ware, the residual silver being finally fused with a small quantity of lead and cupelled. This Parkes process has become well established in the United States, and has received here some useful improvements in the details of its application.

3. *Processes carried out in the liquid way, the silver, as one of its compounds, being brought into solution and afterwards precipitated.*

These methods have of late years received a moderate degree of extension, although their importance as regards aggregate result is trifling in comparison with amalgamation and smelting. The Ziervogel process, involving the production of silver sulphate by careful roasting of the ore without common salt, and extraction of this sulphate with hot water, has perhaps made more progress than chlorination by roasting with salt, followed by washing out of silver chloride with brine or solution of sodium thio-sulphate. Experiments have been made in the United States with Plattner's chlorination by means of chlorine gas, followed by leaching to extract silver chloride, and also with Ziervogel's process combined with subsequent amalgamation of the washed residue.

Gold.—The great discoveries of gold in California and Australia, first in the form of sand and nuggets in river gravel, have proved important, not only in the wealth they have afforded within thirty years, and the movements of population and rapid extension of civilization they have given rise to, but in the stimulus given to study of the modes of occurrence of the precious metal and the best methods for its extraction. Not only have existing riverbeds been explored, but vast masses of alluvium from water currents that have for ages ceased to flow are washed over, and by mechanical arrangements which, starting from the simple pan in the hands of the laborer in 1849, have culminated in the hydraulic mining of the present day, employing sometimes the force of a jet of water six inches in diameter, projected with the pressure due to a head of more than four hundred feet. Before long the attention of the seekers after gold washings was attracted to the veins of auriferous quartz, and gold diggers became gold miners; improvements were made in the mechanical appliances for crushing quartz upon a great scale, and in the amalgamation process for extracting the gold from it; this source of material having for years past grown in importance as the richer stream and dry alluvial works remaining have waned in number and extent. Finally the gold existing in microscopic or even ultra-microscopic particles distributed through masses of pyrites, galena, blende, carbonate of lead, etc., and associated with other ores, as of silver, has come into requisition, and ore by hundreds of thousands of tons is worked which does not contain on an average as much as ·0001 of its weight of gold. Much of the ore from even the great "bonanza" of the Comstock lode might not many years ago have passed under the eye of an experienced miner without its containing useful metal of any sort being suspected. The only strongly-marked contrast to such material has been presented by the marvelously rich pockets and small veins of tellurides in Colorado, very limited in extent, but furnishing sometimes small lots of ore worth $40,000 or $50,000 a ton.

The defects, mechanical and chemical, of the processes in use for the extraction of gold lead to immense losses in absolute value, such as may be counted by millions of dollars annually. It has been estimated, by comparison of the results actually obtained on the large scale with those of careful assays, that quartz amalgamation involves a loss of 12 to 15 per cent. of the gold actually present, while probably still poorer returns are obtained by hydraulic treatment of alluvial gravel, 15 to 30 per cent. of the gold *exposed* being supposed to be lost.

The methods for collecting by smelting the generally very small quantities of gold from pyritous ores and those of lead and zinc are essentially the same as in the case of silver, above alluded to, and the same progress has been made of late years; in fact both the precious metals are commonly obtained together in the matte or base bullion, from which the inferior metals are separated by the same operations. Although these smelting processes yield in the aggregate far less gold than is obtained by washing and amalgamation, there is reason to believe that it is obtained with a less proportion of loss.

The chlorination process of Plattner has been used to but a moderate extent. It demands very careful roasting of sulphurous ores as a preliminary step. The use of bromine, now obtainable at a very low price, seems worth attentive consideration, especially if combined, as it might be, with arrangements for recovering the bromine.

As regards the separation of gold and silver from each other, the long-known method of "parting" by solution of the latter metal in acid is varied mainly as respects the kind

* Cinnabar, accompanied as usual by small quantities of native mercury, occurs at sundry points not only in California, but northwards in Oregon, Washington Territory, and Idaho. The deposits which up to the present have proved practically important are confined to the first named State.

* As has been often pointed out, the patio process is applicable in regions where want of fuel forms an obstacle to the use of quicker methods.

of acid used, European practice having for the most part long since settled down upon hot, concentrated sulphuric acid, while at very large refining works in San Francisco local conditions some time ago caused nitric acid to be preferred, one of these conditions being understood to be the trouble there of disposing of sulphur dioxide economically without nuisance, while the lower oxides of nitrogen can be carried into the furnaces and their oxygen taken up by the fuel.* The immense supply of "argent doré," as the bullion is called which the ores of the Comstock lode in Western Nevada yield by amalgamation, has for several years placed the San Francisco works on a most favorable footing for the application of the parting process, since the bullion contains on an average about 4·75 per cent. of gold by weight in proportion to silver, and therefore needs no addition of the latter metal to secure complete separation by the acid. When gold is the predominant metal, and it becomes necessary to dilute it by further alloy—the old process of "quartation"—in order to avoid cloaking and protection of the portion of the mass which the acid should dissolve, it has not long since been proposed to replace silver, which has hitherto been generally used as the diluting metal, by one of less value, and it has been shown that zinc, added to the extent of five to eight times the weight of the bullion to be treated, may be very easily alloyed with it at a comparatively low temperature, while nitric acid will afterwards readily dissolve out zinc, silver, copper, etc., leaving the gold fine. If this be brought into use on the large scale, the more costly nitric acid might in all probability be dispensed with by dissolving out the zinc first with diluted sulphuric acid, and then boiling the residual metallic sponge with the same acid in the concentrated state so as to take up the silver and copper.

Much merit attaches to the ingenious chlorine gas process, invented by Mr. F. B. Miller, of the Sydney Mint, New South Wales, for separating the two precious metals when alloyed with gold in excess.† He passes a stream of gaseous chlorine down into a crucible containing the alloy in a state of fusion until the silver is converted into chloride, decants this off, recovers a little gold from it by refusion with a small amount of sodium carbonate, and then, casting it into slabs, reduces to metallic silver by means of zinc and a little dilute sulphuric acid. This process, which has since its publication been applied in European refining works, is as well fitted for the special service of dealing on the spot with the large masses of Australian gold bullion, as the San Francisco "parting" is applicable to the silver bullion of Nevada.

Platinum.—The most important change in the method of working the refractory alloy which constitutes what is called native platinum has been the introduction of Deville's process for dealing with it by purely furnace means, avoiding the tedious and expensive solution in aqua regia, and separation by subsequent precipitation as originally proposed by Wollaston, and exclusively practiced since the beginning of the century. The main features of Deville's process consist of fusion with galena and litharge, separation of the osmiridium left undissolved, cupellation of the platiniferous lead alloy obtained, and fusion of the residue left upon the cupellation hearth by means of a stream of ignited oxygen and hydrogen or coal gas in a furnace of compact lime. Although this method has been used upon the large scale, and much platinum has been worked by it, it is said to have lost favor with the principal manufacturers and to have already fallen out of use. The product obtained by it is not pure platinum,‡ but an alloy with iridium and rhodium mainly, better capable, it is true, than the pure metal of withstanding the action of acids and other chemical reagents, but harder, less freely malleable, and more troublesome to work mechanically. On the other hand, Deville undoubtedly deserves the credit of having given practical shape to the *fusion* of platinum in large masses, substituting this more perfect mode of producing compact ingots for the troublesome and less satisfactory *welding* which alone Wollaston has been able to employ. This feature of the new process has become thoroughly established, and will without doubt be permanently retained in use.

METALLIC ALLOYS.

Among the most interesting and valuable materials of this class which may be called new, or comparatively new, may fairly be named the following:

Aluminum Bronze—a result of the experiments made by Deville upon an industrial scale with metallic aluminum, consists usually of about 90 per cent. copper (which should be of the greatest attainable purity) and 10 per cent. aluminum, although these proportions are subject to variation. It may therefore be looked upon as gun-metal in which tin has been replaced by aluminum. It is distinguished by a bright yellow color which may be made closely to imitate that of gold, by capability of resisting in a very high degree both tensile and compressive strains and abrasive friction, by rigidity and remarkable elasticity, while it readily furnishes sound castings and may be forged with satisfactory results.

Phosphor-bronze—a modified gun-metal, was first produced, and carefully tested on a large scale (after several earlier experiments looking in the same direction by others, as Abel in England, and Ruolz in France) by Montefiore-Levy and Kuenzel of Belgium, in 1870–71. It consists of copper and tin, either in the proportions for ordinary gun-metal, viz., 90 per cent. copper, and 10 per cent. tin, or, preferably, with an increase in the amount of the former and diminution of the latter metal, some of the best results being obtained with about 5 or 6 per cent. of tin, while in either case a little phosphorus is added. Of this last element, added in the form of a previously prepared phosphide of tin, a variable portion burns out during the fusion of the alloy, but a small amount is retained, ranging from a small fraction of 1 per cent. up to a maximum of about 2 per cent. Its effect seems to be threefold, first to eliminate, by combining with any oxygen which may exist in the copper-tin alloy,§ whether as oxide of one or both metals, or occluded in the free state, thus tending to increase and assure the homogeneity and compactness of the alloy; secondly, by supplying a more easily oxidizable element to prevent burning out of tin during the fusion and casting of the alloy, thus rendering the proportion between the two metals more definite and permanent; and thirdly, so far as any phosphorus remains in combination in the alloy, to notably increase its hardness, the effect of even a very small proportion being comparable in this respect with the effect of combined carbon on iron in ordinary steel. The most prominent general properties of the alloy are great tensile strength (in some specimens an increase on that of ordinary bronze in the ratio of 5 to 2), rigidity, hardness, consequent resistance to abrasion, and elasticity. Results of a remarkable character were obtained in trials made, under the auspices of the Belgian Government, of this alloy as the material for field artillery, although these results were not without drawbacks in regard to this special application. For portions of the machinery of powder mills, and for hand tools used in such works and in powder magazines, for the cartridge cases of breech-loading firearms, for pump-cylinders and the screw propellers of sea-going vessels, and with certain changes in the character of the alloy* leading to the pretty uniform distribution of hard metal through a softer basis, for the bearings of shafts and other moving portions of machinery, this material has approved itself as of real value. Its general interest is very great, as opening up a field for investigation in regard to the steel-like modification of alloys of the softer metals.

Manganese argentan or German silver.—The very large consumption of the alloy of copper, nickel, and zinc, known as German silver, in reality a hardened and whitened brass, as the material for spoons, forks, and other articles requiring mechanical strength and rigidity, to be afterwards plated over with silver, has of late years met with interference from the increasing rival demand for nickel to be itself galvanically deposited upon other metals, and a certain degree of importance attaches to the manufacture, at first experimentally by several persons, as Parkes of England, and Montefiore-Levy and Kuenzel of Belgium, and since on an industrial scale, of a similar alloy in which nickel is replaced by manganese either wholly or in part, the following being some of the proportions used:

Copper	54·50	55·50	52·25	50·00
Manganese	25·50	13·00	22·25	5·00
Nickel	.....	.....	.....	10·00
Zinc	20·00	31·50	25·50	35·00
	100	100	100	100

Analogous alloys, to which tungsten is also added, have of late been made by Biermann of Hanover. The general character of such material enables it to be used instead of the ordinary German silver, although the hardening tendency of manganese is strongly marked, and unless properly regulated easily leads to trouble from cracking of the alloy in working. The increased tendency to oxidation seems also to call for attention.

Iridio-platinum.—The material finally agreed upon by the International Bureau of Standard Weights and Measures as that to be used in making the new, and, it is hoped, permanent standards of weight and length, consists of 90 per cent. platinum and 10 per cent. iridium. It has been produced in masses of magnificent dimensions, one fusion, under the direction of Deville, having turned out 250 kilogrammes at a single operation, while Matthey, of the firm of Johnson and Matthey, of London, has made rules for geodetic measurements, each of 4 meters in length by 21 millimeters wide and five mm. thick.

The high density of the alloy—21·512 at zero—its malleability, coupled with a considerable degree of hardness, its rigidity and elasticity, capability of receiving a beautifully polished surface, and sharp, delicate graduation lines, and its inalterability by any ordinary chemical exposure, all appear to fit it remarkably well for the use being made of it, and to justify the choice of the International Bureau; yet it seems fairly to admit of question whether any alloy or any compound or mixture is to be preferred for such a purpose to an elementary metal, such as platinum, about whose homogeneity, uniformity of physical properties, and above all permanence of character, less doubt may well be entertained.

Our knowledge in regard to alloys in general has received valuable extension from the researches of Matthiessen,† conducted more particularly with gold, silver, copper, tin, and lead. It is greatly to be desired that his investigations, cut short by too early death, should be resumed, and carried forward with similar intelligence, accuracy, and desire for the discovery of general principles rather than of immediately applicable facts merely.

A recent (1876) observation of a general kind, and novel in itself, has been made by Prof. Silliman in regard to the possibility of conferring sonorous elasticity upon soft alloys, as of tin with antimony, copper, etc., such as "Britannia metal," by a peculiar method of tempering, articles cast from such alloys being immersed for a short time, from a few seconds to a minute or more, in a bath of paraffin oil or melted paraffin, heated to a temperature about 3° C. below the fusing point of the alloy, hence usually to 220°–230° C.

ELECTRO-METALLURGY AND OTHER ALTERATIONS OF METALLIC SURFACES.

The practical substitution, on an industrial scale, of dynamo-electric machines for galvanic batteries, in the production of the current needed for electroplating, as may now be witnessed in New York and doubtless in other cities, is worth noting as one illustration of the more economical series of transformations of the potential energy of coal by which electricity is now made available for useful purposes. The simplicity of application, easily worked arrangements for varying the strength of the current and its adjustment to resistance, and several collateral advantages, as of cleanliness and durability, render these machines very satisfactory. It would be interesting to have a full report on the different forms in use for this particular purpose, with specifications of the first cost, expenditure of driving power, work done, etc.

To the three metals, the deposition of which has for forty years been the chief work accomplished by electro-metallurgy—viz., copper, silver and gold—has now (since 1870) been fairly added a fourth in nickel, whose successful introduction we owe to Mr. Isaac Adams, of Boston. His observation that double salts of nickel and *ammonium* afford solutions from which the metal may be readily thrown down as a coherent and lustrous film, forms the basis of the already important nickel plating. The nearly white color of the metal, its hardness, superior to that of silver, its but slight tendency to tarnish or rust on exposure to oxygen, sulphur compounds, water, or other commonly occurring atmospheric substances, with its cheapness in comparison with silver or gold, combine to make it extremely valuable for a multitude of applications requiring the protection and concealment of iron, brass, copper, and other of the baser metals. In tenacity, hardness, and resistance to chemical alteration, cobalt, which is deposited under like conditions, seems to stand upon nearly the same footing with nickel, while in color it is perhaps superior, being bluish rather than yellowish gray, and when polished presenting a nearer resemblance to silver. The sparing occurrence, however, of cobalt ores, and the large demand for cobalt oxide and silicate in connection with glass staining, porcelain painting, and the manufacture of pigments, tend to limit the scale upon which this metal can be used for plating.

Although the reproduction of engravings was among the first applications of electro-metallurgy, the rapid growth of this application, its expansion in new directions, and the immense extent to which for some years past it has been made serviceable in connection with printing, both of matter at first set up with movable type and of engraved work of the most various kinds, cannot be overlooked amongst novel features of modern industry. In this direction both forms of electro-metallurgy are made useful; the superficial coating of one material with another, as in the harder surface given to ordinary type by the deposition of copper, nickel, and even occasionally iron; and the plastic reproduction of an engraving or a page of type, multiplying with wonderful rapidity and perfect accuracy the printing surfaces from which the myriad impressions upon paper are to be stricken off.

There still remain some applications of the electric deposition of metals obviously desirable but not yet satisfactorily made. One of these as yet unsolved problems seems to be the production of a really good calico printing cylinder of cheaper material than massive copper, and having the intaglio pattern accurately and rapidly transferred to the surface by electro-metallurgy. Improvements in the means of treating the existing cylinders, removing old patterns from them and replacing by new ones, have diminished the importance of this question, but it still remains worthy of examination.

With regard to other alterations of the surface of metals, partly mechanical and partly chemical, the last few years have seen continued and rapid extension of long known processes, such as the tinning of sheet iron, which has received the stimulus of enormous demand for the product arising from the employment of "canned" provisions on a scale far beyond that of even ten or fifteen years ago; the coating with zinc or so called "galvanizing" of iron, which has been in considerable degree stimulated by the stretching forth of scores of thousands of miles of telegraph wire and the increasing use of iron roofing; the production of "malleable" iron castings for innumerable purposes, especially house fittings and builders' furniture, locks, hinges, and the like, the softening of which by superficial burning out of carbon is effected with noticeably greater success and uniformity than used to be attained; and the opposite manufacture of articles of forged iron, "case-hardened" by superficial addition of carbon to form a steely coating, mechanics' tools of various sorts furnishing a wide field for the cheap and useful application of this alteration of surface.

Among the more novel industries of this sort may be mentioned the recently (1877) introduced process of Barff for protecting iron from rust by exposure to superheated steam at a predetermined temperature and for a properly regulated time. The result is the coating over the surface with a very hard and closely adherent layer of magnetic oxide. That this general result is not in itself new is manifest, a thinner coating of the same sort having long been used for the same purpose, upon parts of fire arms for instance, and the comparative exemption from rust of the black surface of iron bars from a rolling mill, and fresh forged work from the blacksmith's hammer, being due to the same cause. In this respect the florid language used by sundry reporters of the supposed new invention is far from being justified. But real merit undoubtedly attaches to the special method by which the object in question is secured,* and to the care with which the details seem to have been worked out. It is stated that if superheated steam at 500° F. be used, and the exposure of the articles to be protected be continued for five hours, a surface is obtained which will resist emery paper for a considerable time, and which will not rust within doors after any moderate degree of exposure to moisture; while if the oxidizing process be conducted at 1,200° F., and continued for six or seven hours, the surface will resist a rasp and will bear prolonged exposure to the weather out of doors. The oxidation does not affect the appearance of the surface otherwise than by turning it black, the texture of the surface remaining unaltered, whether it be that of a rough forging, of a turned or a polished object.

There can be no doubt that for many purposes the protection against rust thus given the surface of iron will be valuable, and if the assertions made in regard to the thoroughly firm adhesion of the film of magnetic oxide, even under conditions of greatly and rapidly varied temperature, prove to be sustained, and the anticipations of the inventor of the process, that it may be applied to the plates of steam boilers and of iron ships, be successfully carried out into practice, this may perhaps be ranked as one or more of the not very numerous list of methods of first-class importance for usefully modifying the surface of worked metals.

THE SALTS OF COPPER.

THE innocuousness of these salts is due in part to the fact that when they are absorbed in considerable quantity they cannot be kept on the stomach, but produce vomiting. It remained to be discovered whether the salts of copper act as poisons on animals which are incapable of vomiting. At the last meeting of the Society of Biology M. Gallipe, according to *La Nature*, gave an account of some new experiments that he had been making in regard to this. Several rabbits were fed on food mixed with copper. One of the animals, during six months, took 36 grains daily of the acetate of the metal, and at the end of that period had become very fat. Its liver weighed 70 grammes and contained 13 centigrammes of copper. Moreover, this same rabbit was eaten by the experimenters without any ill effects.

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*In San Francisco, in connection with the employment of sulphuric acid, precipitation of the silver sulphate by a hot, concentrated solution of ferrous sulphate, has been brought into use instead of the metallic copper precipitation.

† This process is also available as the means of toughening such gold as is occasionally found to be brittle and mechanically intractable from the presence of traces of certain of the baser metals, such as lead, antimony, bismuth, etc.

‡ Nearly, if not quite, all the platinum of commerce contains at least traces of iridium, but in the product of Deville's method of treatment iridium and rhodium occur in quantity varying from 2 or 3 to 25 per cent.

§ Phosphorus has also been very successfully used, as phosphide of copper, to aid in the removal of oxygen by the "poling" process for the production of refined and *tough* copper.

* Addition of lead, which causes segregation of the alloy on cooling into two portions, the one being a hard and tough phosphor-bronze containing very little lead, the other a much softer alloy, consisting chiefly of lead with a small proportion of tin and traces of copper. Railway axle-bearings on the Great Central Railway of Belgium wore out a kilogramme of ordinary gun-metal for 9,900 kilometers run, while the same quantity of the phosphor-bronze and lead alloy was worn out for 429,900 kilometers.

† Brit. Assoc. Rep., 1863; Proc. Roy. Soc., xi and xii.; Phil. Mag. xiii., etc. Some researches of general interest have lately been published by Roberts on alloys of silver and copper (Proc. Roy. Soc., xxiii.), and by Riche on alloys of copper and tin (Ann. Chim. Phys. [iv.] xxx.).

* Mr. G. Bower has also experimented upon the production of a coating of magnetic oxide by exposure of the iron to heated air at regulated temperature, and by like exposure to air mixed with carbon dioxide (gaseous products of combustion), followed by a stream of carbon monoxide, which leads to ferric oxide being first formed, to be afterwards reduced to the magnetic oxide.

THE BEGINNINGS OF LIFE.

WHAT are the simplest forms under which life can manifest itself in nature? Can these forms be produced spontaneously? Are the ordinary physical forces, acting upon oxygen, hydrogen, and nitrogen, capable of uniting these elements in such a way as to form living beings comparable, as respects their origin, with simple chemical compounds? Such are the grave questions that we propose briefly to examine in the present article.

There was a time when life was thought to be the result of organization. The words "living being" and "organism" were then synonymous, and by "organism" we understood an assemblage of parts of a different nature, so combined as to produce those two marvels that we call a vegetable or an

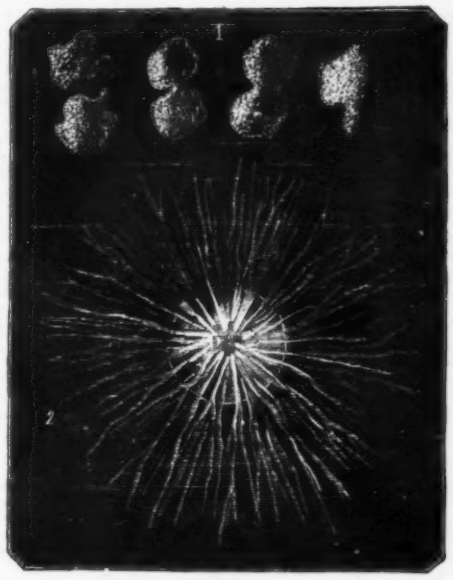

FIG. 1.—1. Reproduction of *Protamœba primitiva*. 2. *Myxastrum radians*.

animal. To-day, however, very different ideas are held as to the conditions necessary for the manifestation of life. Recent discoveries have made known to naturalists living beings that are more wonderful, by reason of their extreme simplicity, than are the most perfect organisms by reason of their complex structure.

A lump of jelly! That is all that we see in them by means of our most powerful microscopes. But this jelly is endowed with life; at every instant we see it changing form, seizing animals of a higher order, dissolving them, and incorporating them into its own substance. This lump of jelly grows and reproduces itself. Sometimes it is absolutely transparent; in the liquid that surrounds it, it appears like those delicate filaments which undulate in a glass of water above a bit of melting sugar; or, at other times, its mass is permeated with very fine granules, almost always in motion through a circulatory current, which causes them little by little to traverse the whole mass. A similar movement is exhibited in the different parts of the body of a great number of animals, and in the thickness of the tissues of several plants. Hitherto it has received no explanation, but it has been called protoplasmic circulation; and we will speak, hereafter, of the living elementary substance itself as protoplasm.

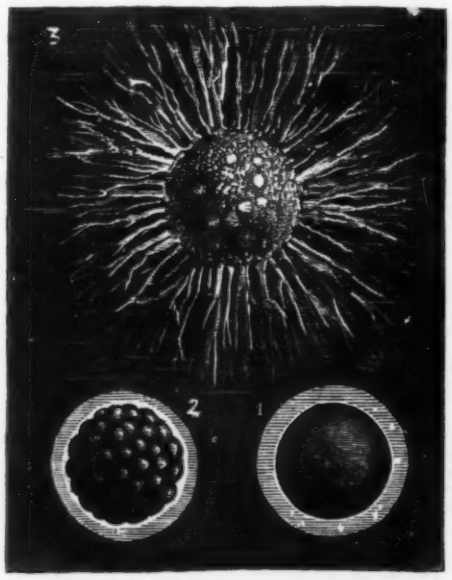

FIG. 2.—*Protomyxa aurantiaca*.—1. *Protomyxa encysted*. 2. Segmentation of the Interior of the Cyst. 3. The Animal with its Pseudopodia.

As long ago as 1830, Dujardin defined the principal properties of this substance and called it sarcode. His studies were made on infusoria; but these microscopic beings are extremely complicated in comparison with those of which we are about to speak, and the existence of which was revealed by Prof. Hæckel, of Jena, who designates them as Monera, on account of their extreme simplicity.

Hæckel observed the first moner in 1864 at Villefranche, near Nice. It was a sort of gelatinous sphere, containing in its substance a few paler granules, and its whole surface was beset with delicate radiating filaments, capable of elongating or contracting in all possible ways. These can even enter into the general mass, and disappear entirely, to be immediately replaced by others; so their existence is then entirely temporary. It is, in fact, the living jelly itself—the protoplasm—which thus stretches out at its surface to produce these apparent arms, these pseudopodia, which serve the animal for creeping, seizing its food, and even digesting it. This is, indeed, life under the simplest form that we can conceive of; all the functions exercised by a single homogeneous substance; and reproduction a simple consequence of the division of the mass into two equal parts. So Hæckel at once saw in his moner of Villefranche what he believed

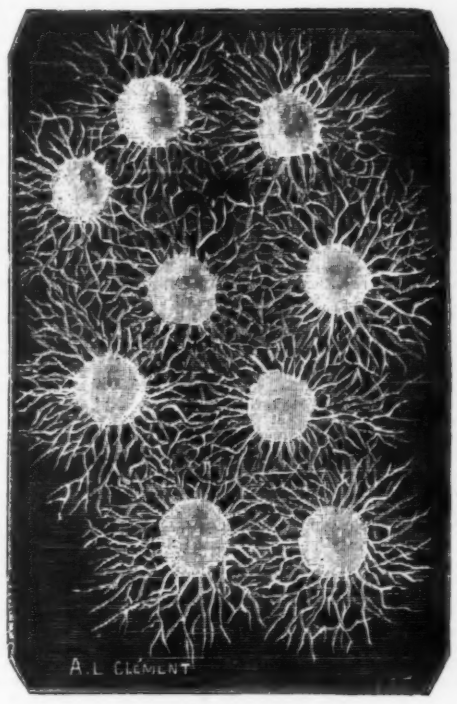

FIG. 3.—*Myxodictium sociale*.

to be a representative of the first living forms, as they must have appeared spontaneously on the globe; and hence the name that he gave this singular being—*Protogenes primordialis*. It should be noted that Protogenes is a pretty clearly defined type, and not a being absolutely amorphous, as one might be led to conceive of the primitive living substance.

Another moner, *Protamœba primitiva* (Fig. 1), also detected by Hæckel, is still more simple than the former. Indeed, its form is entirely undefined; its contours are changing at every moment, but its mass never stretches out into filaments, like the pseudopodia of *Protogenes*. *Protamœba*, as it crawls over the slide of the microscope, appears like a small drop of grease; like the preceding species, it never grows beyond a certain size, but when it has attained a few hundredths of a centimeter, it divides, like *Protogenes*, and forms two distinct individuals.

There has been found in the ocean, at a depth of 25,000 feet, a moner still more simple yet than the preceding. Huxley detected in the dredgings made by the English ship Por-

FIG. 4.—*Protomyxa aurantiaca*, after having captured numerous Infusorias.

cupine, reticulated protoplasmic masses, which he named, in 1868, *Bathybius Hæckeli*. This species would seem to grow constantly without the necessity of segmenting, and to be continuously forming and developing on the ocean bottom, covering it with a living layer of indefinite extent, and heir, perhaps, of the animate slime from whence all beings have emanated—mother of the fauna and flora of the future.

Unfortunately, the existence of *Bathybius* has been vigorously disputed by various scientists, who argue that it is merely a gelatinous precipitate of sulphate of lime. Hæckel, however, maintains the reality of this mysterious being; and some recent discoveries, if they do not prove him right, at least demonstrate that there certainly do exist living masses analogous to those described by Huxley. Bessel has gathered protoplasmic masses in the polar seas, and which, in their fresh state, have exhibited "magnificent amœboid movements." These masses differ only from *Bathybius* in not containing those calcareous concretions that have been designated as coccolites, discolites, or cyatholites, but they exhibit a very clearly defined protoplasmic circulation. If, then, Huxley's *Bathybius* be doubted, it does not seem that Bessel's *Protobathybius* should be. The latter scientist has

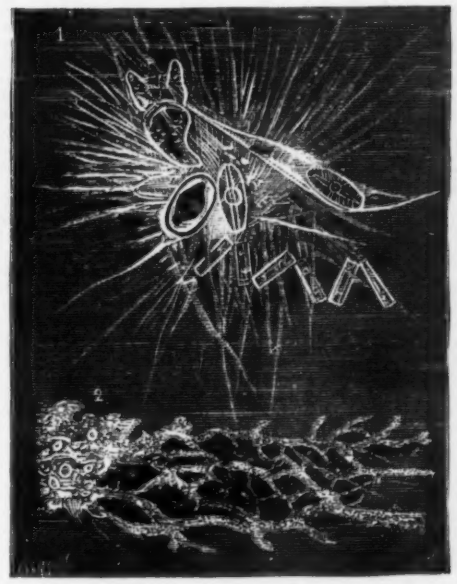

FIG. 5.—1. *Myxastrum radians*, after absorbing Diatoms and Infusorias. 2. Protoplasmic Net-work of *Myxodictium sociale*.

described another moner, under name of *Hæckelina gigantea*, which is more complicated, and the individuals of which unite in colonies, without becoming confounded. This is also the case with *Myxodictium sociale* (Fig. 3), described by Hæckel, and which has the appearance of an assemblage of *Protogenes* united by their pseudopodia.

A talented young naturalist, Prof. Schneider, of Poitiers, has just found an allied animal in damp earth (Figs. 3 and 5). Finally, Prof. Greef, of Marbourg, has brought to light protoplasmic masses in fresh water, which he calls *Pelobius*, and which seem to play the same part in our ponds and water courses that *Bathybius* does in the sea.

In these beings there is, so to speak, no individual. In another series of moners, on the contrary, individuality asserts itself more and more, and reproduction is exhibited as a very distinct function. There is no longer a simple division of a body into two parts; but there is a formation of special reproductive bodies, very simple, however, and not confined to moners, but also found in inferior plants and animals; and these we may call spores. The *Protomonas* so well investigated by the Russian naturalist, Cienkowski, are small moners with short but filamentous pseudopodia. Some inhabit fresh water, as *Protomonas amyli*, others are marine species, as *P. gomphonematis*. At a certain period of their existence, the *Protomonas* retract their pseudopodia and become transformed into small and perfectly regular

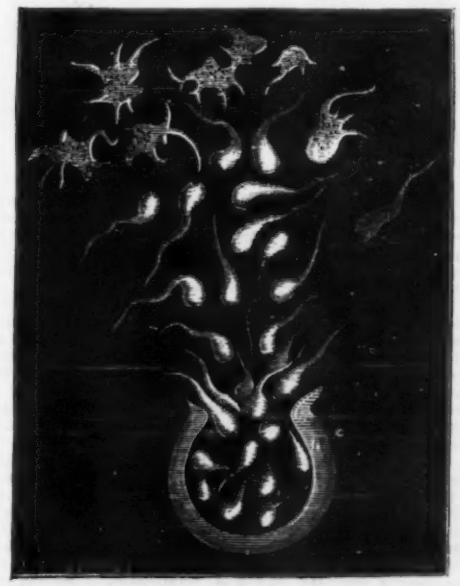

FIG. 6.—Cyst of *Protomyxa aurantiaca* ruptured, and showing the Flagelliform and Amœboid phases of the Zoospores.

spheres. The external layer of the sphere becomes more resistant than the rest of the protoplasm and forms a sort of membranous cyst in which the protoplasm undergoes segmentation into quite a number of small globular masses. Then the cyst ruptures and the masses escape. (Fig. 6.) These little globular masses, at the time of their escape from the cyst, become pyriform, the smaller end being prolonged into a delicate filament, and by the undulatory movement of this the young spore is enabled to move about rapidly in the water. Soon, pseudopodia start out from the entire surface of the reproductive body, and the filament becomes confounded with them; then a number of the spores thus modi-

fied assemble together, become completely fused, and reconstitute a *Protomonas*.

The *Vampyrella*, also discovered by Cienkowski, differs especially from *Protomonas* in having only four spores in its cyst. Many species of the genus inhabit fresh water, and their bodies exhibit the most varied forms. They are extremely voracious, and feed exclusively on vegetable matters (Fig. 7, Nos. 2 and 3).

A method of reproduction analogous to that of the *Protomonas* is exhibited by a splendid moner found in the Isle Lancerote (one of the Canaries), and described by Hæckel under the name of *Protomyxa aurantiaca* (Figs. 4 and 6). The *Protomyxa* is usually found on abandoned shells, and is easily recognized by its beautiful orange color. It elongates in every direction its ramified pseudopodia, always in search of small infusoria and crustaceans, whose carapaces are for a long time recognizable in the gelatinous mass which has nourished itself at their expense. When it has grown sufficiently, it behaves exactly like the *Protomonas*, drawing in its pseudopodia, inclosing itself in a membrane, and then becoming segmented into a multitude of orange-colored spores, exactly like those that we have before described. These spores, in order to become transformed into *Protomyxa* have only to increase in size and put forth pseudopodia, and this they do very soon (Figs. 2 and 4).

Myxastrum (Fig. 5) is a moner quite similar, except in color, to *Protomyxa*. It differs especially from the latter in that its spores are placed in a radiating manner around the center of the cyst.

The forms that living beings made up of an entirely homogeneous substance can assume—forms so simple that it is difficult to conceive of anything more so—are, as may be seen, very numerous; and it is very probable that there are a great many yet to be discovered. The rapid glance that we have just taken leads us to conclusions of great importance. As simple as the substance which forms the moneras is, it exhibits very different properties in each species; and this would imply that the protoplasm, as far as a sole, fundamental, living substance is concerned, is a mere abstraction. We already know as many distinct protoplasms as there are existing moners, and each one of these protoplasms reproduces itself, not only with all of its physical and chemical properties, but with all its physiological properties too. Yet all these substances possess a certain number of properties which are common to them: all execute spontaneous movements; all increase and assimilate foreign matters, that they fashion by their simple contact in such a manner as to render them identical with themselves; all exhibit a tendency to form small individual masses, which are capable of being resolved into still smaller masses, fitted for being transformed into new individuals. In other words, all protoplasms move, eat, and, as a necessary consequence, reproduce their like. These are almost the only properties that are common to them, and they are characteristic of protoplasmic life. But, properly speaking, these properties, united in one substance, constitute what we call life.

Fig. 7.—1. *Actinosphærium Eichhornii* devouring Stentors. 2 and 3. *Vampyrella*, one of which has devoured Diatoms, and the other (3) has absorbed the contents of an Alga Cell.

As to the secondary properties which distinguish protoplasms from each other, we may ask whether they are original or acquired. If the latter, we should find out whether all protoplasmic substances are not derived from a single primitive substance eminently fitted to become modified under the action of certain influences, possessing only the property of moving and of increasing its mass by assimilating foreign matters—a substance formed by the free action of physical forces.

Such is the form under which the question of spontaneous generation presents itself to-day. We admit as demonstrated that all beings that have acquired any degree of individuality whatever could not have been produced spontaneously; but we ask whether the non-individualized protoplasm cannot spring up spontaneously, and whether conditions have not existed where it may have had birth after the manner of ordinary chemical compounds. No decided answer has been made to these questions, which presuppose, moreover, the existence of a primitive living substance other and more simple than those that we know. It must be added, however, that in no case has this spontaneous formation been observed. Observation shows every day masses of protoplasm in the act of reproduction, but it has never shown it in the act of being formed. Yet, some scientists have gone so far as to assert, that, seeing the rapid and continuous progress of organic chemistry, it is not too much to hope that one day means will be found to accomplish the synthesis of protoplasm, and thus create life in the laboratory. If it be true that protoplasm is only a chemical compound, the innumerable and magnificent conquests made by organic chemistry within less than fifty years are well calculated to encourage such a hope. It was believed at the beginning of the present century that a whole class of substances called organic could only be formed in the tissues of animals and plants. Since that time almost all have been obtained artificially, and every day some new progress is made in the field pointed out by the eminent chemist Berthelot. In truth, the substances most allied to protoplasm (nitrogenized substances like the white of an egg, and thence called albuminoid) still resist; but everything leads to the belief that they will not do so long. The power of chemists is, then, very great. But can we see in their labors anything that may lead us to believe that this power is great enough to create the living substance itself? It would appear not. In all that chemists have obtained hitherto, we indeed see products of life, but not life itself. Albuimnoid substances are fitted for preserving life, but they do not live of themselves. Even had it been possible to manufacture them artificially, life would not have been created for all that. The fact would only have demonstrated that all the chemical compounds that life is fitted to make use of, can be produced by the physico-chemical forces.

Besides, there are fundamental differences between protoplasm and chemical compounds that are easy to establish. Ask a chemist the definition of any compound whatever, and he will answer by giving you its chemical composition, and this composition characterizes it in an absolute manner. Now try to apply this definition to protoplasm, and it will be found impossible, for the chemical composition of this singular substance is eminently variable, not only according as we regard such and such an animal or plant, but also according as we consider such and such a part of the same animal or plant. And more—and this is the very essence of protoplasm—the same lump of this strange substance rarely preserves its identity, even for a short time. Every substance that lives, also feeds, that is, assimilates foreign matters that go to increase its mass; and these matters, in proportion as they are dissolved, change its chemical composition; it is, then, in a perpetual state of transformation, and this is a difference which widely separates protoplasm from every chemical compound in which the proportions of the constituent elements can be modified without causing it to disappear by the operation. Protoplasm acts on the substances which surround it by incorporating them. It thus increases its mass and modifies its chemical composition, but the fundamental, the vital properties that characterize it, remain identically the same. Chemical compounds, on the contrary, when they act on substances with which they are brought in contact, become themselves decomposed.

To sum up, beings composed solely of this primordial jelly, beings formed of a single, homogeneous substance, are, as yet, few; but there is a host of others scarcely more complicated, which live in immense quantities in all parts of the globe—in moist earth, as well as in fresh water and in the ocean depths.

We do not speak here of those legions of *Bacteria*, *Vibrios*, *Spirillums*, and *Mycoderms*—half-solid, microscopic corpuscles, whose mission seems to be to give up to the mineral world dead organic beings; nor do we speak of those to-be-dreaded *Micrococci*, that are agents of the gravest diseases, such as small pox, purulent infection, croup, etc. In simplicity, all these beings are true moners, distinguished from those that are already known by their extreme minuteness and their invariable form.

It is not the same with those beings designated by materialists as Rhizopods, and which resemble the moners in their faculty of emitting protoplasmic prolongations, or pseudopodia, and which differ from them in possessing certain new productions in the midst of their substance. One of the most important of these productions is called the *nucleus*, and is a sort of concretion, sometimes paler than the living matter that surrounds it, sometimes granular and darker, in both cases almost always exhibiting another and smaller internal concretion called the *nucleolus*. We do not know the nature of the nucleus and its nucleolus, but it is very certain that both play a very important part in the physiology of the beings that exhibit them.

The *Amœbas* differ from the *Protamœbas* merely in possessing a nucleus and a nucleolus. Some *Amœbas*, in addition to their nucleus, exhibit a sort of membrane which either covers a part of their body, as in *Arcella*, or forms a kind of little bottle, through the neck of which the animal thrusts out its pseudopodia, as in *Gromia*. Sometimes, as in *difflugia*, this membrane is glutinous, so that grains of sand, shells of infusoria, microscopic shells, etc., become fastened to its surface. All these beings are closely allied to each other and to the protamœbas; and their pseudopodia are always rounded and bulky. In certain stagnant waters, we find in great abundance a being of extreme elegance which, on the contrary, is allied to the *Protogenes* and moners, and this is the *Actinophrys sol*, the center of which is occupied by a dark nucleus, and the circumference surrounded by a multitude of very slender radiating filaments. This animal is reproduced by self-division.

We also frequently find in still waters the *Actinosphærium Eichhornii*, as large as the head of a pin, and visible to the naked eye. It scarcely differs from actinophrys, except in its central mass being composed of a large number of nuclei instead of a single one (Fig. 7). Other forms of our fresh waters are still more complicated, and of a wonderful regularity and elegance of form; but these we shall speak of in a succeeding article.

[Continued from Supplement 186.]

Translated from *La Correspondance Scientifique*.

THE BEGINNING AND END OF THE WORLDS—II.

By Camille Flammarion.

THE END.

We all of us admire to-day the beauties of terrestrial nature, the verdant hills, the perfumed meadows, the purling brooks, the mysterious shades, the groves animate with singing birds, the mountains crowned with glaciers, the immensity of the seas, the warm settings of the sun in clouds edged with scarlet and gold, and the sublime glimmering of the sun on the mountain tops when the first rays of the morning shiver in the gray mists of the plain.

We admire the human works which to-day crown those of nature; the bold viaducts thrown from one mountain to another, and over which speeds steam; the ships, marvelous structures traversing the ocean; the brilliant and animated cities; the palaces and temples; the libraries, museums of the mind; the arts of sculpture and painting, which idealize the real; the musical inspirations which make us forget the vulgarity of things; the works of the intellectual genius who explores the mysteries of the world and transports us into infinity; and we live in happiness in the midst of this life so radiant, making ourselves an integral part of it. But all this beauty, all these flowers and these fruits will pass away. The earth was born; she will die. She will die either of old age, when her vital elements shall have been used up, or through the extinction of the sun, to whose rays her life is suspended. She might also die by accident, through collision with some celestial body meeting her on her route; but this end of the world is the most improbable of all.

She may, we repeat, die a natural death through the slow absorption of her vital elements. In fact, it is probable that the air and water are diminishing. The ocean, like the atmosphere, appears to have been formerly much more considerable than it is in our day. The terrestrial crust is penetrated by waters which combine chemically with the rocks. It is almost certain that the temperature of the interior of the globe reaches that of boiling water at a depth of about six miles, and prevents the water from descending any lower; but the absorption will continue with the cooling of the globe. The oxygen, nitrogen, and carbonic acid which compose our atmosphere also appear to undergo absorption, but slower. The thinker may foresee, through the mist of ages to come, the epoch, yet afar off, in which the earth, deprived of the atmospheric aqueous vapor which protects her from the glacial cold of space by concentrating the solar rays around her, will become chilled in the sleep of death. As Henri Vivarez says: "From the summit of the mountains a winding sheet of snow will descend upon the high plateaus and the valleys, driving before it life and civilization, and masking for ever the cities and nations that it meets on its passage." Life and human activity will press insensibly toward the intertropical zone. St. Petersburg, Berlin, London, Paris, Vienna, Constantinople, and Rome will fall asleep in succession under their eternal shroud. During very many ages equatorial humanity will in vain undertake arctic expeditions to find again under the ice the place of Paris, Lyons, Bordeaux, and Marseilles. The seacoasts will have changed, and the geographical map of the earth will have been transformed. No one will live and breathe any more except in the equatorial zone up to the day when the last family, nearly dead with cold and hunger, will sit on the shore of the last sea, in the rays of the sun which will thereafter shine here below on an ambulant tomb revolving aimlessly around a useless light and a barren heat.

It seems that our neighbor, the moon, younger than the earth, since she is her daughter, but lighter and weaker, has already lost the greatest part of her liquids and her gases; for the innumerable craters that pierce her with their yawning mouths have been able to vomit forth their fiery entrails, amid the spasmodic convulsions that agitated her, only at an epoch when the lunar atmosphere must have been incomparably thicker than it is to-day.

Perhaps, without knowing it, we are taking part in the death agonies of the last tribes of humanity who are fighting up there against the invasion of cold and death. Ah! if these celestial neighbors could only speak to us telegraphically and tell us their history!

The planet Mars, formed prior to the earth, is smaller, and appears also to be more advanced than we; for her seas do not, like ours, occupy three-fourths of the globe. Doubtless the Martial humanity has now reached its apogee, while we have scarcely left our stage of infancy and barbarism.

But perhaps the earth will live long enough to die only on the extinction of the sun. Our fate would be all the same, in truth (it would be death by cold just the same), but it would be longer coming. In the first case, nature is certainly reserving us for some millions of years yet of existence; in the second, the stadia of the future would have to be numbered by millions of ages. Humanity will be transformed physically and morally long before reaching its apogee, long before it diminishes.

The sun will be extinguished. He is constantly losing a part of his heat; for the energy that he expends in radiation is, so to speak, beyond the power of imagination. The heat emitted by this star would cause to boil per hour, 2,900 million myriameters of water at the temperature of ice! Almost all this heat is lost in space. The quantity that the planets arrest on its passage and utilize for their life is insignificant as compared with the amount lost. We can calculate, for instance, what fraction of this heat the earth receives. For this, it suffices to conceive of an immense hollow sphere surrounding the sun (the sun being in the center), and the surface of the same being at the same distance from the sun that we are, that is to say, at 95 million miles. The disk of the earth is to the total superficies of this immense ideal sphere as 1 is to 2,300,000,000. So the solar heat lost on the side of the earth, in immensity, is two thousand three hundred million times greater than that which our globe intercepts and utilizes! All the planets combined arrest only an infinitesimal portion of this immense radiation.

If the sun is now still condensing sufficiently fast to compensate for a like loss, or if the rain of aerolites, which must be constantly falling on his surface, is sufficient to make up the difference, the sun is not yet cooling; but if the contrary be the case, his cooling has already begun. The latter is the more probable, for the spots which periodically cover him can scarcely be considered anything but an evidence of cooling. The day will come when these spots will be much more numerous than they are at present, and in which they will begin to mask a notable portion of the solar globe. From age to age the obscuration will increase gradually, but not regularly, for the first fragment of crust that covers the incandescent liquid surface will soon give way, to be replaced by new formations.

Future ages will see the sun several times extinguished and relighted, up to the far off day in which the cooling shall definitely take possession of the entire surface; when the last intermittent and wan rays shall vanish for ever; and when the enormous red ball shall darken, never again to return to enliven nature with the sweet benefit of light. It is the end of time as sung to his lyre by the chanter of Rolla:

> "'Tis Nothingness! see'st how its somber shade immense
> Creeps slowly there upon the flaming sun?
> The shadow gains, extends; th' eternal days commence?"

Already have we seen twenty-five stars sparkle in the heavens with a spasmodic glimmer and fall into an extinction allied to death; and already certain brilliant stars saluted by our fathers have disappeared from the maps of the heavens. The sun is but a star, and he will undergo the same fate as his sisters. Suns, like worlds, are born only to die, and in eternity their long career will have lasted only the space of a morning.

Then the sun, a dark but still warm star, electric and doubtless vaguely lighted by the waving flashes of the magnetic aurora, will be an immense world inhabited by strange beings. Around it will continue to revolve the planetary tombs, until the day when the solar republic all entire shall be erased from the book of life, and disappear to give place to other systems of worlds, to other suns, to other earths, to other humanities, to other souls—our successors in universal and eternal history.

(To be continued.)